W. B. No. 682

U. S. DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

CHARLES F. MARVIN, Chief

MONTHLY WEATHER REVIEW

VOLUME 47, No. 4

APRIL, 1919

WASHINGTON
GOVERNMENT PRINTING OFFICE
1919

INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological and seismological contributions and bibliography; (2) an interpretative summary and charts of the weather of the month in the United States and adjacent oceans; and (3) climatological and seismological tables dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (*a*) results of the observational or research work in meteorology carried on in the United States or other parts of the world, in the weather Bureau, at universities, at research institutes, or by individuals; and (*b*) abstracts or reviews of important meteorological papers and books. In each issue of the REVIEW such contributions and abstracts are grouped by subjects, roughly, in the following order: General works, observations and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture, weather, applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but the publication of such contributions is not to be construed as official approval of the views expressed.

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library U. S. Weather Bureau, Washington, D. C.," in order that the monthly list of current works on meteorology and seismology may be as complete as possible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW.

The section on the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans, and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meterological Service of Cuba.
The Meteorological Observatory of Belen College, Havana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

Supplements containing kite observations and others containing monographs are published from time to time.

SOME WEATHER BUREAU PUBLICATIONS.

A few of the more recent Weather Bureau publications are listed below, with their prices. A complete list may be obtained upon application to the *Chief, U. S. Weather Bureau.*

To secure such publications as have a price affixed, one should apply to and make remittances payable to the *Superintendent of Documents, Government Printing Office, Washington, D. C.* Stamps and personal checks are not accepted in payment. Additional charge for postage for foreign addresses.

National Weather and Crop Bulletin, with charts, monthly from October to March, weekly during remainder of the year	25c. a year.
Snow and Ice Bulletin, with charts, weekly during the winter	25c. season.
Climatological data, monthly for 42 separate sections, each section 5c. a copy	50c. a year.
Complete monthly number, 42 sections	35c. each, $4.00 year.
Monthly Weather Review Supplement No. 9. (Periodical events and natural law as guides to agricultural research and practice)	25c.
Monthly Weather Review Supplements Nos. 10 and 11. (Aerology Nos. 5 and 6), 1917 kite data	25c. each.
Monthly Weather Review Supplements Nos. 12 and 13. (Aerology Nos. 7 and 8), 1918 kite data, etc	25c. each.
Weather forecasting in the United States	$1.25
The daily weather map, with explanation (text and 4 charts)	5c.
Instructions for cooperative observers, 5th ed. Circulars B and C combined	10c.
Instructions for the installation and operation of Class A evaporation stations. Circular L	10c.
Papers on meteorology as a subject for study. (Repr. from Dec., 1918, Mo. Wea. Rev.)	10c.
Report of the Chief of the Weather Bureau, 1917–1918 (4° edition)	Free.
Modern methods of protection against lightning. (Farmers' Bull. No. 842)	Free.
Notes on the climate of France and Belgium	Free.
The Weather Bureau. (Descriptive pamphlet)	Free.
Explanation of the weather map (leaflet)	Free.
Serial numbers of Weather Bureau publications	Free.
General classification of meteorological literature (leaflet). (Repr. from Jan. 1919, Mo. Wea. Rev.)	Free.

As the surplus of MONTHLY WEATHER REVIEW SUPPLEMENT No. 2 is limited, recipients who do not care to retain their copies will confer a favor by notifying the Chief of Bureau, who will arrange for the return postage.

CORRIGENDA.

REVIEW, January, 1919:

Page 29, second column, third line above the diagram, *for* "one-hundredths" *read* "one-hundredth."

Page 30, Table 2, Rio Grande, 1913, second column, *for* "5.544" *read* "5.844". Same table, Brazos Brook, 1909, fourth column, *for* "5.566" *read* "5.366". Same table, Gatun Lake, 1911, twelfth column, *for* "3.376" *read* "5.376."

FIG. 1 (B. J. S. & A. T. W.).—Beginning of a pilot-balloon run at Fort Omaha, Nebr.

FIG. 2 (B. J. S. & A. T. W.).—Making a reading at the end of the first minute, Gerstner Field, La.

MONTHLY WEATHER REVIEW

HERBERT H. KIMBALL, Acting Editor.
CHARLES F. BROOKS, Associate Editor.

VOL. 47, No. 4.
W. B. No. 682.

APRIL, 1919.

CLOSED JUNE 3, 1919
ISSUED JULY 10, 1919

CONTRIBUTIONS AND BIBLIOGRAPHY.

AEROLOGICAL INVESTIGATIONS OF THE WEATHER BUREAU DURING THE WAR.

By WILLIS RAY GREGG, Meteorologist.

INTRODUCTION.

Washington's advice, "In time of peace prepare for war," has never received the emphasis which his experience and prophetic vision have deserved. Fortunately, however, peace-time pursuits can often be adapted to war-time necessities, and we see overnight, as it were, the conversion of science and industry—whose only purpose *should be* to contribute to the welfare of humanity—into vast laboratories and factories, whose one purpose is to inflict as much destruction upon the enemy as human ingenuity, skill, and industry can accomplish. Thus, a nation's merchant marine becomes a fleet of transports; its steel plants a network of munition factories; and its colleges and universities a series of military camps. Again, its chemists and physicists devote their attention entirely to devising the most destructive agents possible, and its engineers to the construction of camps, pontoons, etc., and to the transportation and placement of huge engines of war.

In line with all other activities, the Weather Bureau was suddenly called upon at the beginning of the war to curtail as far as possible its usual program of furnishing advice and warnings to those engaged only in peaceful pursuits and to adapt itself to war-time conditions. Happily, many of the investigations that had been conducted by the Weather Bureau enabled it to furnish exactly the kind of information most needed by the military and naval services. Again, its trained personnel, though inadequate in numbers to take care of all the meteorological observations and investigations required at the front and in this country, nevertheless formed the nucleus around which a large organization was developed for that purpose. Thus, some of these men went directly to France and organized an extensive meteorological service there; others remained in this country and devoted their time and energy to establishing observing stations at military and naval camps; to the training of promising young men for assignment to duty as observers; and to the furnishing of data, information, and advice, whenever called for, as soon as possible and as accurately as possible. Several papers have appeared (see particularly MONTHLY WEATHER REVIEW, December, 1918) outlining the scope of these endeavors. The purpose of this sketch is to indicate briefly a few additional lines along which the Weather Bureau endeavored to "do its bit" toward the winning of the war.

AEROLOGICAL INVESTIGATIONS PRIOR TO THE WAR.

Prior to the war between the United States and Germany aerological investigations had been conducted by the United States Weather Bureau principally as follows:

(*a*) At a large number of well distributed stations during the period April to November, 1898;

(*b*) At Mount Weather, Va., and auxiliary stations from 1907 to 1914, inclusive; and

(*c*) At Drexel, near Omaha, Nebr., from 1915 to March, 1917, inclusive.

Campaign of 1898.—The work in 1898 consisted of "hand" kite flights to comparatively low altitudes. The data were published in detail and discussed by Prof. H. C. Frankenfield in Weather Bureau Bulletin F. One of the chief results of this campaign was the standardization of kites, meteorographs, and other apparatus through a long series of experiments by Prof. C. F. Marvin and Mr. S. A. Potter. Moreover, certain points were brought out in connection with the suitability of sites for stations with respect to proximity to centers of population, power lines, freedom from forested tracts, etc.

Mount Weather and auxiliary stations.—A longer-continued and more systematic series of observations was conducted at Mount Weather, Va., by means of kites and captive balloons. In addition, there were made during this period several short series of observations with sounding balloons at different points in the central and western States, viz., at Indianapolis, Ind., and Fort Omaha, Nebr., in September and October, 1909; at Fort Omaha, Nebr., in May, 1910; at Huron, S. Dak., in August and September, 1910; at Fort Omaha, Nebr., in February and March, 1911; at Avalon, Calif., in July and August, 1913, in connection with captive balloon ascensions at Lone Pine and Mount Whitney, Calif.; and at Fort Omaha, Nebr., in July and August, 1914. The data obtained at Mount Weather and its auxiliary stations were published in the bulletin of the Mount Weather Observatory and in the MONTHLY WEATHER REVIEW, together with several papers by Dr. William R. Blair and others, among the most important being "The Five-Year Summary for Mount Weather," "The Diurnal System of Convection," and "The Planetary System of Convection." Although the location of Mount Weather was far from ideal in many respects, it is not too much to say that the information derived from the observations made there and elsewhere under Dr. Blair's direction were of

incalculable value in connection with the war. Without this information the Weather Bureau would have been seriously embarrassed, if not humiliated, in its inability to furnish free-air data, and opinions based on these data, to the military and naval authorities.

Drexel, Nebr.—During 1914 and 1915 the work conducted at Mount Weather was transferred to Drexel, Nebr., because of the better location of the latter place with respect to storm tracks and to the needs of the forecasters. The general plan of the work at Mount Weather was continued at Drexel, but special attention was given to the diurnal variation of the several meteorological elements. Only the field work was carried on at Drexel, the computing and summarizing being done at the Central Office. Owing to the fact that the clerical force assigned to the Aerological Division was inadequate, the computing of the Drexel records was considerably in arrears, and but little information could therefore be furnished as to mean free-air conditions at that station.

Other investigations by the Weather Bureau.—A systematic campaign of cloud observations at Washington, D. C., in 1896–97, furnished much valuable information as to cloud altitudes and movements and therefore as to wind direction and velocity at various heights. Following the work of the *Scotia*, in 1913, a short series of kite flights on the Coast Guard cutter *Seneca* in May and June, 1915, gave some data as to free air conditions at low altitudes over the North Atlantic Ocean in the vicinity of Nova Scotia.

Blue Hill Observatory.—This report would be incomplete unless reference were made to the long and excellent series of observations made under the auspices of the Blue Hill Meteorological Observatory, founded and for many years maintained by the late Prof. A. Lawrence Rotch. These investigations included observations with kites at Blue Hill, near Boston, Mass.; with sounding balloons at St. Louis, Mo.; and with sounding and pilot balloons at Pittsfield, Mass. The results were published and ably discussed in different numbers of the Annals of the Harvard College Observatory. They have, moreover, been studied and used, to some extent, by the Aerological Division in connection with similar results obtained by the Weather Bureau.

PREPARING FOR WAR.

Although the work thus briefly reviewed was of great and permanent value, yet it lacked one vital and essential characteristic, viz, simultaneity of observations from a large number of well-distributed stations. Accordingly, as soon as a state of war was declared to exist between the United States and Germany, suitable action was taken for the expansion of the aerological activities of the Weather Bureau, with the result that Congress incorporated in the Army bill for the fiscal year 1917–18, an act "For the establishment and maintenance by the Weather Bureau of additional aerological stations, for observing, measuring, and investigating atmospheric phenomena in the aid of aeronautics, including salaries, travel, and other expenses in the city of Washington and elsewhere, $100,000, to be expended under the direction of the Secretary of Agriculture."

This act did not become operative until July 1, 1917, but plans for carrying out its provisions were made as soon as the Army bill was passed, viz, May 12, 1917. Before establishing the additional stations, however, it was necessary to provide a well-trained personnel and to obtain suitable equipment. These phases of the work, together with the furnishing of data, cooperation with the Army and Navy, establishment of special stations of a temporary nature, publications, etc., will henceforth be treated under separate heads.

PERSONNEL.

At the beginning of the war, as already stated, the Aerological Division comprised one field station at Drexel, Nebr., and a headquarters office at the Central Office in Washington, D. C. Ten men in all were engaged in the work—six at Drexel, with Mr. B. J. Sherry in charge, and four at Washington, with Dr. Wm. R. Blair in general charge of the entire division. In enlarging this personnel a double purpose was kept in view: (1) To train young men to conduct the work at field stations and (2) to train certain others for permanent assignment at Washington in connection with the reduction and summarizing of the data. It was decided that at least the official in charge and the first assistant at each station to be established should receive training of both kinds in order that they might become familiar with all phases of the work. This procedure served the additional purpose of enabling the Central Office force to bring the work of computing free-air records up to date. As rapidly as the men became thoroughly familiar with this work they were temporarily assigned to a field station for instruction in kite flying, kite repairing, etc., and were later permanently assigned to one of the new stations. In the meantime some of the men and several young ladies were permanently assigned to the Central Office, and not only brought the work up to date but have kept it up to date ever since. During the early part of September, 1917, Dr. Blair was commissioned a major in the Signal Corps and assigned to duty in France, and in the latter part of October, 1917, Mr. Sherry was commissioned a lieutenant in the Signal Corps and assigned to the National Research Council in connection with the organization of a military meteorological service in this country and in France.

EQUIPMENT.

Kite reels.—At the beginning of the war the division had on hand two kite reels—one at Drexel and one at the Central Office. As it was planned to establish five additional stations, action was taken to have four more of these reels constructed. These were delivered in time for use and have proved satisfactory. They are of standard type, after the design of Prof. C. F. Marvin, with some modifications by Dr. Blair. A view of one of these is shown in figure 2.

Reel houses.—The reel house at Drexel, Nebr., having proved satisfactory, it was decided to use this as a model, except that the size was reduced from 18 to 15 feet in diameter. These houses consist essentially of two parts—a turntable, by means of which the doorway may be presented to any desired direction, and a superstructure sufficiently large to accommodate the kite reel and accessory apparatus. Suitable turntables were procured and shipped to the respective stations, where they were mounted on concrete bases, the turntables themselves supporting the wooden superstructures. Views of the reel houses complete may be found in MONTHLY WEATHER REVIEW SUPPLEMENTS Nos. 12, 14, and 15.

Surface instrumental equipment.—All apparatus for recording surface meteorological conditions is of standard type, such as is used at regular Weather Bureau stations.

Kite meteorographs.—The meteorographs in regular use by this division are of the type designed by Prof. C. F.

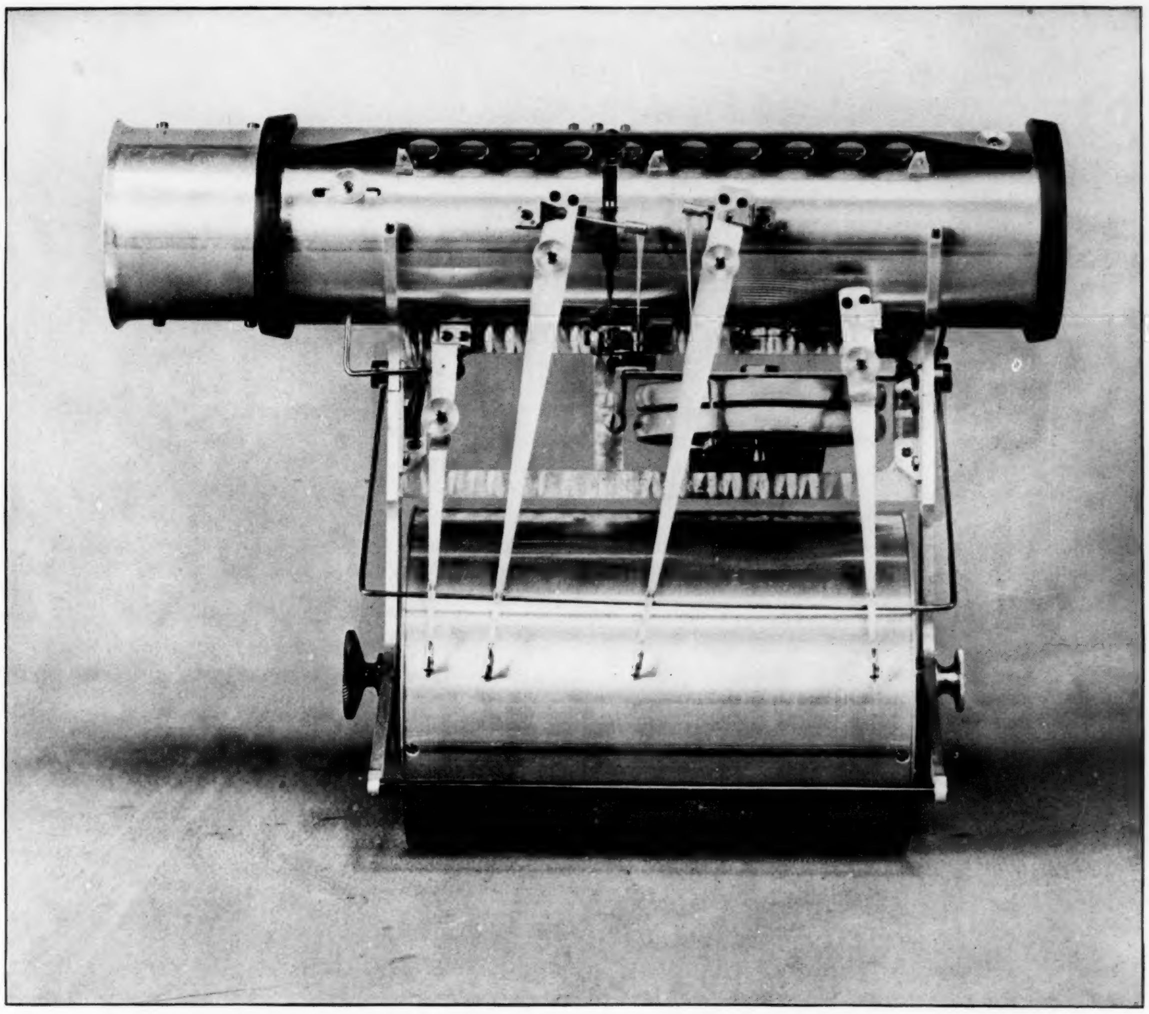


FIG. 1.—Front view of Marvin kite meteorograph in use at Weather Bureau Aerological Stations.

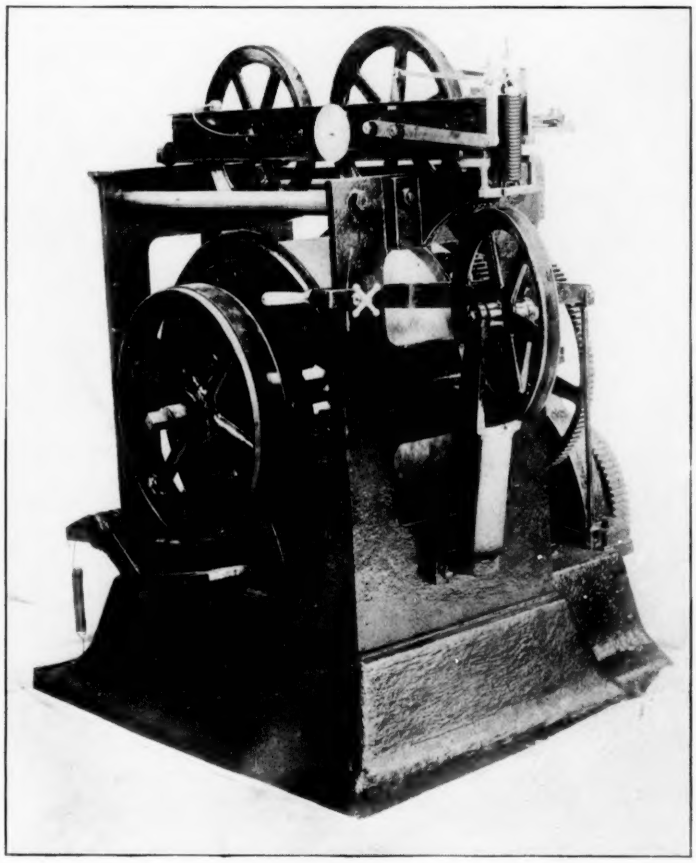


FIG. 2.—Kite reel in use at Weather Bureau Aerological Stations.

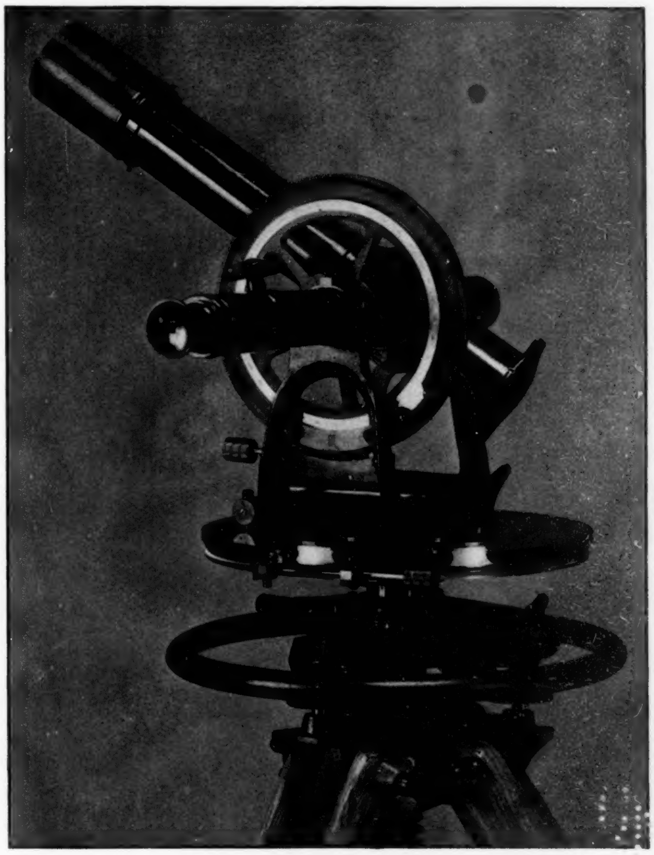


FIG. 3.—Kite and balloon theodolite in use at Weather Bureau, Military, and Naval Aerological Stations.

Marvin, with some modifications as to details of construction. These modifications are: The substitution of a "windmill" anemometer, mounted at the windward or front end of the instrument, in place of the Robinson type, separately exposed on the kite; the substitution of strips of thermostatic metal, consisting of bronze and invar plates, in place of tubes filled with ether, for the temperature element; and a different arrangement of the hairs in the hygrometer, whereby these hairs are mounted separately instead of in bundles. There were about a dozen of these meteorographs on hand and many of them were defective in one way or another. It became necessary, therefore, to repair those on hand and to procure several additional instruments. After some correspondence with instrument makers, it became apparent that the best course to pursue was to purchase the necessary materials and have the new instruments made in our own shop. Such action was accordingly taken, but even then great delay was experienced, owing to the fact that all manufacturers were pressed to the limit by war work. Delay was greatest in the case of clocks and pressure elements of these instruments. When these were finally procured, they proved to be very satisfactory, and a large number of new instruments were constructed, in addition to several old ones which had meanwhile been repaired and made ready for use. A front view of one of the new meteorographs is shown in figure 1.

Kites.—Each regular station needs at least 25 kites of different sizes in order that flights may be made under different conditions of wind velocity. It seemed wise to have all of these kites made at one station, in order to avoid duplication of power saws and other equipment. Accordingly, Drexel was designated a "central" station and the necessary materials for about 150 kites were sent to that station and made up into standard box kites of the Hargrave-Marvin type, such as have been regularly used by the Weather Bureau in all of its aerological investigations. By means of improvements in equipment and by concentrating on certain parts of the kites and then successively on other parts it has been possible to produce a large number in a short time, and in fact each station was supplied as soon as it was ready for them.

Theodolites.—The division had on hand four of these instruments, formerly in use at Mount Weather, but they had become, in general, unserviceable by reason of long use and through unavoidable accidents. Two self-recording theodolites, designed by Dr. Blair, were intended for use in sounding-balloon work. This latter type, but without the recording feature, was deemed the most satisfactory one for the kite stations and, accordingly, orders were placed for 16 of these. Only five were delivered during the war, but they were sufficient for the stations thus far established and have proved satisfactory for the purpose. In addition to these, and acting upon the recommendation of this division (aerological), the Meteorological Section of the Signal Corps placed similar orders for a large number of theodolites for use at military training fields in this country and at the front in France. A view of one of these theodolites is shown in figure 3.

Pilot balloons.—The use of pilot balloons was not at first contemplated by this division, it having been decided that this work should more properly be handled by the Meteorological Section of the Signal Corps. However, pending the organization of that service and in order to save time, sample pilot balloons were obtained from different companies and tested at the Central Office. On the basis of these tests orders for large numbers of these balloons were placed by the Signal Corps, and it is understood that they have been used with success at all of the Army Meteorological Stations.

Pressure-testing outfits.—All meteorographs are calibrated at the Central Office before being sent out; after that they are calibrated at the stations at which they are used. For temperature and humidity the instruments are merely subjected to different conditions within a well-ventilated box or in different rooms. For wind they are suspended from a wind vane near a standard anemometer. For pressure, however, it is necessary to have special apparatus consisting of an air pump, a bell jar, and a manometer. Geryk air pumps and bell jars have been obtained from makers of scientific instruments and very satisfactory U-tube manometers, suitably mounted and graduated, have been designed and made at the Central Office of the Weather Bureau.

Motors.—Because of the variation in the pull of the kites on the wire and because, even when the pull is uniform, it is often desirable, for different reasons, to change the speed of reeling in, each kite station should be equipped with a variable speed motor, this variation in speed to be independent of the load to be pulled. Motors of this sort for direct current are on the market, but at some of the stations only alternating current was available. It therefore became necessary to have special motors designed and constructed—two for single-phase and two for three-phase current. After considerable delay such motors were procured and have given excellent results.

PERMANENT KITE STATIONS.

Five stations, in addition to the one at Drexel, were planned, and their approximate locations were indicated by Dr. Blair just prior to his departure for France. The Mount Weather and Drexel stations were situated so far from even a small town that living conditions were not conducive to that contented state of mind which is a prerequisite (more or less, depending upon individual temperament) to the attainment of harmony and the best possible results. Moreover, the cost of maintaining such a station, with its own power plant, etc., is large. In establishing these additional stations it was therefore decided, so far as possible, to select sites a short distance to the east of small towns, where electric power and living quarters for the men would be available and where the least possible difficulty would be experienced from railroads, rivers or lakes, forested tracts, human habitations, etc. Further requirements of a good kite field are that it should be level, cleared of trees, stumps, fences, etc., and have an area of approximately 40 acres. Whenever possible, it was purposed to lease land on which the owner would erect, and include in his lease, a building suitable for office, carpenter shop, and the storage of kites. After a site was selected and as soon as the lease became effective, the installation of equipment was immediately begun. As a rule, the reel house was placed near the center of the field and the buildings and surface meteorological equipment in one corner or near one side of the field. The sites selected are: Broken Arrow, Okla.; Ellendale, N. Dak.; Groesbeck, Tex.; Leesburg, Ga.; and Royal Center, Ind. Detailed descriptions of these stations may be found in Monthly Weather Review Supplements Nos. 12, 14, and 15. See also figure 4 for their locations.

The kite work conducted at these stations has been patterned after that at Drexel and comprises daily observations, whenever possible, and, in addition, about two series of diurnal observations each month. These

latter consist of about eight or nine successive flights, from the records obtained in which it is possible to follow quite closely the diurnal changes in the various meteorological elements at different altitudes. The work at Drexel has been continued as heretofore, in spite of many changes in personnel and in addition to the instruction of new men in kite flying and to a greatly enlarged program in kite building.

TEMPORARY KITE STATIONS.

Potomac Park, Washington, D. C.—At the request of the War Department, a kite station was established at Potomac Park in January, 1918, and several flights at night were made during February and March, 1918, in connection with searchlight tests, conducted by the Engineer Corps. The kite reel was of an old type formerly in use at Mount Weather. This and other equipment were furnished by this division, the power being supplied by the Engineer Corps. During this period there were also made a few flights in connection with experiments in atmospheric electricity by the Bureau of Standards.

Ellington Field, Tex.—During April and May, 1918, several kite flights were made at this field for the purpose of raising devices for the detection of the approach of airplanes. A hand reel, kites, and other equipment were furnished by this division. Owing to the confidential nature of this investigation, no report of the results has been received from the Engineer Corps, but it is known that the apparatus was raised to heights of from 1,000 to 1,500 feet above the surface.

Aberdeen, Md.—In an endeavor to improve the range tables used by the United States Army, the Ordnance Department requested that kite flights be made at the Aberdeen Proving Grounds. Accordingly, the kite equipment formerly used at Potomac Park was installed at that place, and records were obtained with a kite meteorograph, whenever possible. This meteorograph was also used in airplane flights when conditions were unfavorable for kites.

PUBLICATIONS.

Meteorology and aeronautics.—During the First Pan-American Aeronautic Exposition at New York, February 8 to 15, 1917, it was apparent that an urgent need existed for a meteorological manual for aviators. Therefore, such a manual was prepared at the Weather Bureau, and late in the year was published by the National Advisory Committee for Aeronautics as Report No. 13. The purpose, as stated in the Introduction, was "to show the sort of atmospheric data available and to put the subject in such shape as may make it bear directly on the problems which are met in aviation." This pamphlet was given wide distribution, not only in this country but also in France, and helped to fill a long-felt want among aviators, and was used in connection with the instruction of men in the Meteorological Section of the Signal Corps.

Mean values of free-air barometric and vapor pressures, temperatures, and densities over the United States.—Owing to repeated calls by the Army and Navy for mean free-air data, a set of tables, giving the results of all obervations made in this country by the Weather Bureau, was prepared and published in the January, 1918, number of the Monthly Weather Review.

The turning of winds with altitude.—Soon after the publication of "Meteorology and Aeronautics" it became evident that somewhat more detailed information relative to the behavior of free-air winds in relation to those at the surface was needed than was given in that pamphlet. Accordingly, such a paper was prepared and, likewise, published in the January, 1918, number of the Monthly Weather Review. Reprints of these two papers were furnished to training fields and to various Government departments that had sought such data. Moreover, a set of "Rules" for predicting wind conditions aloft, published at the end of "The Turning of Winds with Altitude" was included in a "Manual of Aerography for the United States Navy."

Aerological supplements.—The policy of publishing free-air data in Supplements to the Monthly Weather Review has been continued. At the close of the war all data up to June, 1918, inclusive, had been so published, together with some discussion and illustrations. In Supplement No. 12 is included a brief note on "Free-Air Temperatures During the Cold Winter of 1917–18." This note endeavors to show briefly the value of free-air wind observations in predicting the direction of movement of storm areas. In Supplement No. 13 a paper entitled "Notes on Kite Flying," by Mr. V. E. Jakl, presents useful suggestions for obtaining the best possible records under varying conditions of weather.

Introductory meteorology.—Early in August, 1918, the Weather Bureau was requested by the National Research Council to prepare a textbook on meteorology suitable for use in instructing men in the Students' Army Training Corps. Such a textbook was prepared under the editorial direction of Prof. W. J. Humphreys, who requested the official in charge of the Aerological Division to write Chapter III on Atmospheric Temperature and Chapter IV on Atmospheric Pressure. In the belief that a textbook for use in this Country should contain material largely drawn from this Country's sources of information, the writer of Chapters III and IV based the subjects treated principally on the results obtained at Mount Weather and auxiliary stations—Drexel, Nebr., and Blue Hill, Mass. Numerous charts and figures were included with the text, some of them new, some copied from the Mount Weather Bulletin and the Monthly Weather Review, and some from Prof. Humphreys's "Physics of the Air."

Smithsonian meteorological tables.—In connection with a revision of these tables and at the request of Prof. H. H. Kimball, who had the work in charge, this division prepared the tables for use in computing free-air records, and for the conversion of millimeters into millibars and millibars into millimeters. Assistance was given also in the computation of gradient-wind tables.

SPECIAL DATA FURNISHED.

To the Ordnance Department.—In addition to average free-air conditions, as given in some of the publications above listed, there were frequent calls for information at specified times and places. For example, estimates of free-air densities were requested in connection with anti-aircraft and other tests at the Aberdeen Proving Grounds and the Sandy Hook Proving Grounds, when no actual records were obtainable from kites or airplanes. This division made such estimates in the following manner: By the aid of daily weather maps the days for which estimates were desired were classified with respect to the station's location in different quadrants of the HIGH or LOW which controlled the weather conditions at the times of tests. The mean temperature and humidity gradient for such conditions, as determined from five years' observations at Mount Weather, were then applied to the surface values recorded at the proving grounds. With

these estimated temperatures and humidities, values of pressure and density were readily computed for the various altitudes. Such values were furnished at various altitudes up to 8 kilometers for some 60 tests.

To the Military Intelligence Service.—At the request of the Military Intelligence Service, information was furnished as to the best conditions of pressure distribution that would be favorable for the release of "propaganda" balloons in France, in order that they would reach certain parts of Germany and Austria. The opinions expressed were based in large part on the results of Cave's work with pilot balloons in England, and on those with kites and balloons in France and Germany.

To aviation services.—Information was given to the Air Services of the Army and Navy as to the best conditions under which to attempt trans-Atlantic airplane flights; also as to the best route to follow.

COOPERATION WITH THE SIGNAL CORPS.

Selection and instruction of men.—Early in the war it was decided that the Signal Corps should have a meteorological service of its own for war-time purposes. As has already been stated, Dr. Blair and Mr. Sherry, of this division, were among those transferred from this Bureau to that service. Before this transfer was effected, Dr. Blair selected a number of well-trained college graduates, who, it was expected, would sooner or later be drafted. These men, together with others subsequently selected, were in large measure during the first few months trained in meteorological work by the Weather Bureau. A few of them received special instruction in the Aerological Division.

Equipment.—Before the organization of the Signal Corps Meteorological Service could be perfected, urgent calls for equipment were received from a large number of training fields in this country. In order to prevent delay in complying with these requests, this division supplied complete sets of meteorological apparatus for some 20 military camps and proving grounds. In addition three kite meteorographs were furnished for the use of the United States forces in France.

Free-air forecasting for aviators.—One of the most valuable achievements of the Signal Corps Meteorological Service was the organization at most of the training fields in this country of systematic observations of free-air wind conditions by means of small pilot balloons. The primary purpose of these observations was to furnish helpful information to aviators as to current local conditions and to enable the Ordnance Department to apply ballistic wind corrections to its range tables. But the wide distribution of these stations presented an opportunity for still further usefulness, viz, the plotting or mapping of upper air currents and the issuance of bulletins based thereon for the information and guidance of aviators flying over transcontinental aerial routes. It was, therefore, decided at a conference on July 29, 1918, between Lieut. Col. Millikan, Lieuts. Sherry and Waterman, representing the Signal Corps, and Prof. Marvin, Mr. Calvert, and the writer of this report, representing the Weather Bureau, to carry out this plan, the details of field organization to be worked out by Lieut. Sherry and those of assembling and computing the data and issuing bulletins to be under the general direction of this division. Approximately 25 stations were established at points indicated in figure 4. Five of these were placed at Weather Bureau aerological stations, partly because these stations are well located for the purpose desired and partly in order that Weather Bureau observers might become thoroughly familiar with the work. Two Signal Corps men were assigned to each station and six to the Central Office of the Weather Bureau. Plans were perfected for receiving reports daily by wire, these reports to include wind direction and velocity at the surface and at altitudes of 250, 500, 1,000, 1,500, 2,000, 3,000, and 4,000 meters above it; also, kind, amount, and height of lower clouds, if any. Arrangements were made with the Forecast Division to issue bulletins and forecasts, based on these reports, to the Aerial Mail Service and to any others who might desire them.

COOPERATION WITH THE NAVY.

Pensacola flying station.—In May and June, 1917, Dr. Blair conferred with officials of the Navy at Pensacola, Fla., relative to meteorological equipment that should be installed at that station.

Navy yard.—In June, 1917, Dr. Blair conferred with officials of the Navy at the United States Navy Yard relative to the development of a theodolite for pilot-balloon observations and a plotting device for quickly interpreting those observations.

Aerographic division of the United States Naval Reserve Flying Corps.—Information was given to this service relative to sources of supply for theodolites, pilot balloons, and other equipment. Complete outfits of meteorological instruments and apparatus were furnished for use at some of the stations established. The results of pilot-balloon soundings made at these stations are regularly furnished to the Weather Bureau, and in return advices as to probable future free-air conditions are issued by the Forecast Division.

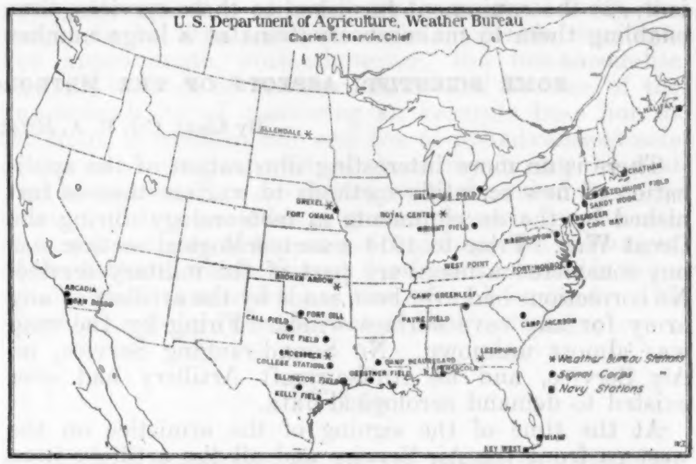


FIG. 4.—Location of Weather Bureau, military, and naval, aerological stations in operation, November, 1918.

In addition to the practical application of the data obtained by the Weather Bureau Army and Navy meteorological services, these data have been and are being studied with a view to the preparation of a summary or manual for aviators, thus bringing the subject of free-air winds in their relation to pressure distribution, etc., up to date.

COOPERATION WITH FOREIGN COUNTRIES.

Great Britain.—In response to a cablegram from Gen. Bartlett, a Marvin kite meteorograph was sent to the British Admiralty in October, 1917. This instrument proved so satisfactory that a request was made for the purchase of six more of them. Owing to the fact that we had on hand not even enough of these instruments

for our own use, it was impossible to comply at once with the British Admiralty's request. Steps were taken, however, to furnish them as soon as possible, with the result that two were sent during August, 1918, and the remaining four shortly after the close of the war.

Italy.—At the request of representatives of the Italian Royal Flying Corps, information was given as to the best conditions of pressure distribution under which to attempt cross-country flights between Hampton, Va., and New York; between Hampton and Chicago, Ill.; and between Chicago and New York.

CONCLUSIONS.

The policy of the Aerological Division was at all times to furnish as quickly as possible the available data, equipment, etc., needed by the military and naval services in the prosecution of the war, and at the same time to increase its facilities for such cooperation by making improvements in its equipment and by bringing together into concise form the results of all aerological investigations, not only in this country but in other parts of the world as well. It is believed that the most important results accomplished have been: (1) The aid rendered the Army and Navy in organizing their meteorological services; (2) the equipment furnished to those services, thus enabling them to make observations at a large number of training fields; and (3) data, information, and advice to the military and naval services relative to free-air conditions, both as to mean values and for specified times and places. Whatever of value has been achieved is due very largely to the never-failing advice and sympathetic support of the Chief of Bureau; to the hearty cooperation of the administrative officers and chiefs of divisions of the bureau; and especially to the industry, enthusiasm, and loyalty of all the employees of this division, both at the field stations and in the Central Office.

AS TO THE FUTURE.

The need for aerological data in peace times will become increasingly urgent. Improvements in aircraft will very likely result in making them less dependent upon weather conditions than at present, but it is not likely that the time will ever come when a knowledge of the air cannot be used to advantage by the aviator. The development of the Aerial Mail Service and of commercial aviation makes it imperative that we continue and expand our upper-air forecasting service. Aside from these considerations free-air observations are so inherently related to surface observations that a study of them as now begun can hardly fail to increase the accuracy of "forecasting the weather."

SOME SCIENTIFIC ASPECTS OF THE METEOROLOGICAL WORK OF THE UNITED STATES ARMY.[1]

By Lieut. Col. R. A. Millikan, Signal Corps, U. S. A.

There is no more interesting illustration of the application of new scientific methods to warfare than is furnished by the developments in meteorology during the Great War. Prior to 1914 a meteorological section was not considered a necessary part of the military service. No corrections had ever been made by the artillery of any army for any save surface winds. Firing by the map was almost unknown. No Sound-ranging Service, no Air Service, and no Anti-aircraft Artillery had ever existed to demand aerological data.

At the time of the signing of the armistice on the western front the Air Service and all the artillery were being furnished every two hours with the temperature, density, wind velocity, and direction, taken at the surface and at various altitudes, from 100 to 500 meters apart, up to 5,000 meters. Further, tables were prepared from which each battery could obtain the correction suited to its trajectory for the so-called ballistic wind. This is the average wind for the trajectory, weighted for the density of the air at the elevations traversed. Even machine guns when used for barrage work made use of these ballistic-wind tables.

In addition, daily forecasts were furnished to the armies in accordance with the following outline:

A. Character of weather for each arm of the service.
B. Winds: Surface, at 2,000 m., and at 5,000 m.
C. Cloudiness, including fog and haze.
D. Height of cloud.
E. Visibility.
F. Rain and snow.
G. Temperature.
H. Warning of weather conditions favorable for use of gas by enemy.
K. Probable accuracy or odds in favor of forecast.*

Most of the aerological data were obtained from theodolite observations on pilot balloons. The extent to which our knowledge of the upper air has been and is being extended by this pilot balloon work may be seen from the fact that before the war there existed but one station in the United States where pilot balloon explorations were regularly carried on. Within a year of the inception of the meteorological service in the United States Army, 37 complete stations for the obtaining of both surface and upper-air data in aid of aviation and the artillery had been established in the United States (see fig. 4, p. —, above) and equipped with special aircraft theodolites and pilot balloons, neither of which had ever been produced before in this country. Further, 20 such stations had been established by our forces abroad. For the manning of this service, about 500 specially selected men had been trained in this country and 314 of them sent abroad, while about 200 were held for work in the United States.

The scientific interest in this service centers about four distinct problems:

1. The extension of our knowledge of the law of motion of pilot balloons.

2. The procurement of data and the development of methods for the preparation of artillery range tables.

3. The development of long-range propaganda balloons.

4. The charting of the upper air in the United States and overseas in aid of aviation.

1. *The extension of our knowledge of the law of motion of pilot balloons.*—Prior to the development of the Meteorological Service of the Army there had been made in the United States perhaps 100 pilot balloon flights, in which the balloons had been followed by the two-theodolite method—the only method which permits of real accuracy; and in several European countries there had

[1] Read before the American Physical Society on Apr. 25, 1919, at Washington, D. C.
* A more detailed account of this work in France is being prepared for the Review by one of the meteorological officers still overseas.—Editor.

been a somewhat greater number, but the data were incomplete and fragmentary.

Within the past year approximately 5,000 such observations have been taken by the Meteorological Service of the Signal Corps. From these observations the altitude of the balloon is determined with great accuracy by triangulation, the base line being usually a mile or more in length. The balloon is kept in sight up to distances as great as 60 miles and up to heights as great as 32,000 meters, or approximately 20 miles. For the practical uses of the artillery and the air service, observations need not be carried higher than 10,000 meters (6 miles), which is the extreme height to which airplanes have thus far ascended or to which projectiles usually go.

In view of the number of variables which enter into the rate of ascent of pilot balloons, such as the changing density and the changing temperature of the surrounding air, the changing size of the balloon and consequent changing tension of the rubber envelope, the changing temperature of its interior because of the absorption of the sun's rays, the diffusion of hydrogen through its walls, etc., it is one of the most striking facts to be found anywhere in the annals of empirical science that these balloons rise to great heights without deviating appreciably from the simplest possible law of ascent, namely, that of constant speed. Graphs Nos. 1, 2, 3, 4, and 5, in figures 1 and 2, show beautiful examples of this constancy. Graph No. 6, figure 2, shows a kink at about 5,500 meters, which is presumably due to a descending current struck at that altitude. Graph No. 7, figure 2, shows a balloon followed to a height of 20,000 meters, where it apparently developed a leak and failed to ascend farther.[1] Graph No. 8 shows the fluctuations which are often found at low altitudes, these fluctuations being undoubtedly due to ascending and descending currents.[2]

The extreme constancy in the rate of ascent shown in a great majority of flights, although surprising enough, is not as inexplicable as it at first appears, for since the pressure within the balloon due to the tension of the rubber itself is only from 5 to 8 centimeters of water, and since this pressure is at sea level less than 1 per cent of the pressure of the atmosphere, it will be seen that the balloon will expand practically freely; that is, as though the walls did not constrain the gas at all, up to heights of, say, 10,000 meters, where the pressure is about a third of an atmosphere. This means that the ascensional force must be entirely independent of temperature and pressure.[3] For the speeds with which these balloons ascend, namely, about 3 meters a second, the resistance to motion must be directly proportional to the density of the air, and experiment shows it to be nearly proportional to the cross-section of the balloon; that is, to the square of the radius. This makes the resistance vary as the cube root of the density,[4] which means that at a height of 6,000 meters, where the density is about one-half, the resistance is 0.83 of what it would be at the surface. If, as is approximately true for these speeds, the resistance varies as the square of the velocity or the velocity as the square root of the resistance, this would mean that the velocity should vary as the sixth root of the density. In other words, since the sixth root of 2 is 1.13, at a height of 6,000 meters the velocity should be about 13 per cent greater than at the surface. Such an increase in velocity would be very easily observable in the experimental data. The fact that it is not found there is due to the wholly fortuitous circumstance that the slow diffusion of hydrogen through the walls, as observation by Blair and Sherry has shown, is just sufficient with the balloons here used to retard the ascensional rate enough to make it quite exactly constant.

This makes it possible, provided one could always duplicate the size and weight of his balloon, to obtain a very exact determination of wind velocity and direction by a one-theodolite method, the height being always known from the time and the known rate of ascent.

When, however, the weight and inflation of the balloons are varied, as they must be in practice, since the balloons vary in weight from 20 to 35 grams, and since it is convenient also to vary the filling according as low altitude or high altitude wind data are desired, it is found that no accurate formula can be found for computing the speed in terms of the ascensional force, the weight to be lifted, and a single invariable constant. For approximate work, however, the one-theodolite method, because of its convenience and because of the impracticability of measuring an accurate base line at the front, is much in use, and one of the advances made in the meteorological work of the Army during the past year has consisted in developing, with the aid of the large amount of data available, a general formula for the rate of ascent in terms of the ascensional force and the weight of the balloon, which, though far from accurate, is more reliable than that which has heretofore been used. The formula heretofore used is that of Dine's, namely:

$$V=K\frac{l^{1/2}}{L^{1/3}}$$

in which V represents the rate of ascent in meters per minute, l is the free lift, or the weight of the displaced air less the weight of the balloon and contained hydrogen, L is the weight of the balloon plus the free lift, and K is a constant.

The formula as modified by the observers of the Signal Corps is

$$V=K'\left(\frac{l^3}{L^2}\right)^{.208}$$

This formula is found to fit the observational data within the ranges used in the Signal Corps work to an accuracy of somewhat less than 10 per cent, which is sufficient for most work at the front.[5]

2. *Meteorology in the aid of the artillery.*—In former times, when guns did not shoot to a greater distance than 8 or 10 miles, it was usually possible to observe where the projectile hit and to correct errors by "spotting." This made unnecessary the correction of the trajectory for the influence of the wind and the changing density of the air with increasing altitude. In the present war, however, guns have been built to shoot much farther and, in addition, camouflage has prevented the visual location of guns, even at the old ranges. Hostile batteries have been located in many instances solely by the new art of

[1] A pilot balloon which appears similarly to have reached a limiting altitude was followed for 258 minutes (and could have been followed for longer) at Murmansk, Mar. 29, 1919. If the computed ascensional rate, 500 feet/min. (152 m./min.) had been assumed to hold throughout the run, the indicated altitude would have been 129,000 feet (39,320 m.). From notes by Capt. W. H. Pick, published in Brit. Met'l Off. Cir., No. 35, May 1, 1919, p. 3.—ED.

[2] See pp. 223–225 below.

[3] For if f_1, d_1, v_1, p_1, t_1 represent ascensional force, density, volume, pressure, and temperature at the surface of the earth, and f_2, d_2, v_2, p_2, t_2, the corresponding quantities at any given elevation, then, since $\frac{d_2}{d_1}=\frac{v_1}{v_2}=\frac{p_2t_1}{p_1t_2}$, (1) and $\frac{f_1}{f_2}=\frac{v_1d_1}{v_2d_2}$, (2) there results from a combination of (1) and (2) $\frac{f_1}{f_2}=\frac{v_1d_1}{v_2d_2}=\frac{p_2t_1}{p_1t_2}\times\frac{p_1t_2}{p_2t_1}=1$.

[4] For if R_1 is the resistance at the earth's surface and R_2 that at any given altitude, $\frac{R_1}{R_2}=\frac{v_1^{2/3}d_1}{v_2^{2/3}d_2}$ which is seen from (1) to equal $\left(\frac{d_1}{d_2}\right)^{1/3}$.

[5] Further details of the development of this formula are given on p. 218, below.

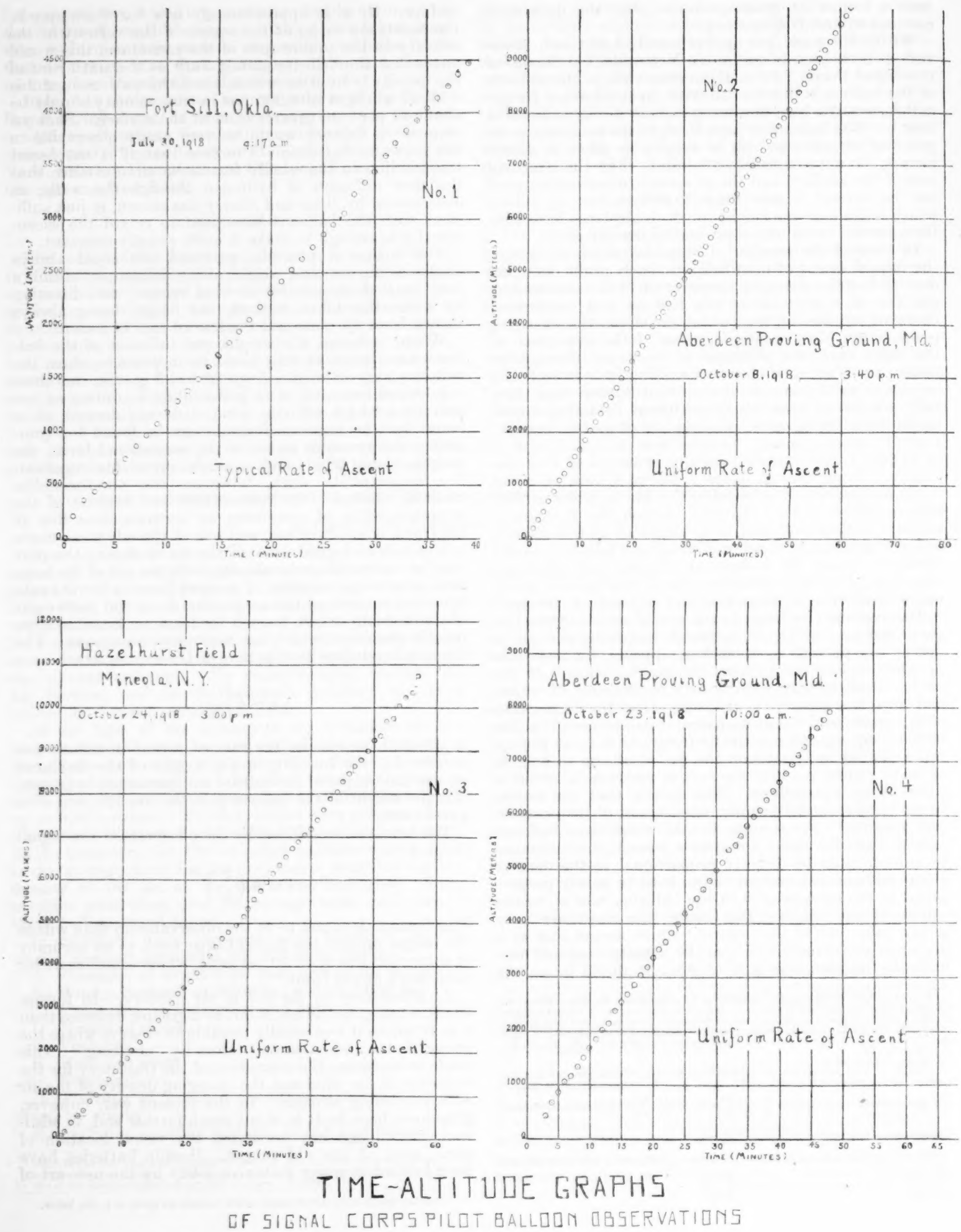


FIG. 1.—Time-altitude graphs of typical pilot balloon runs.

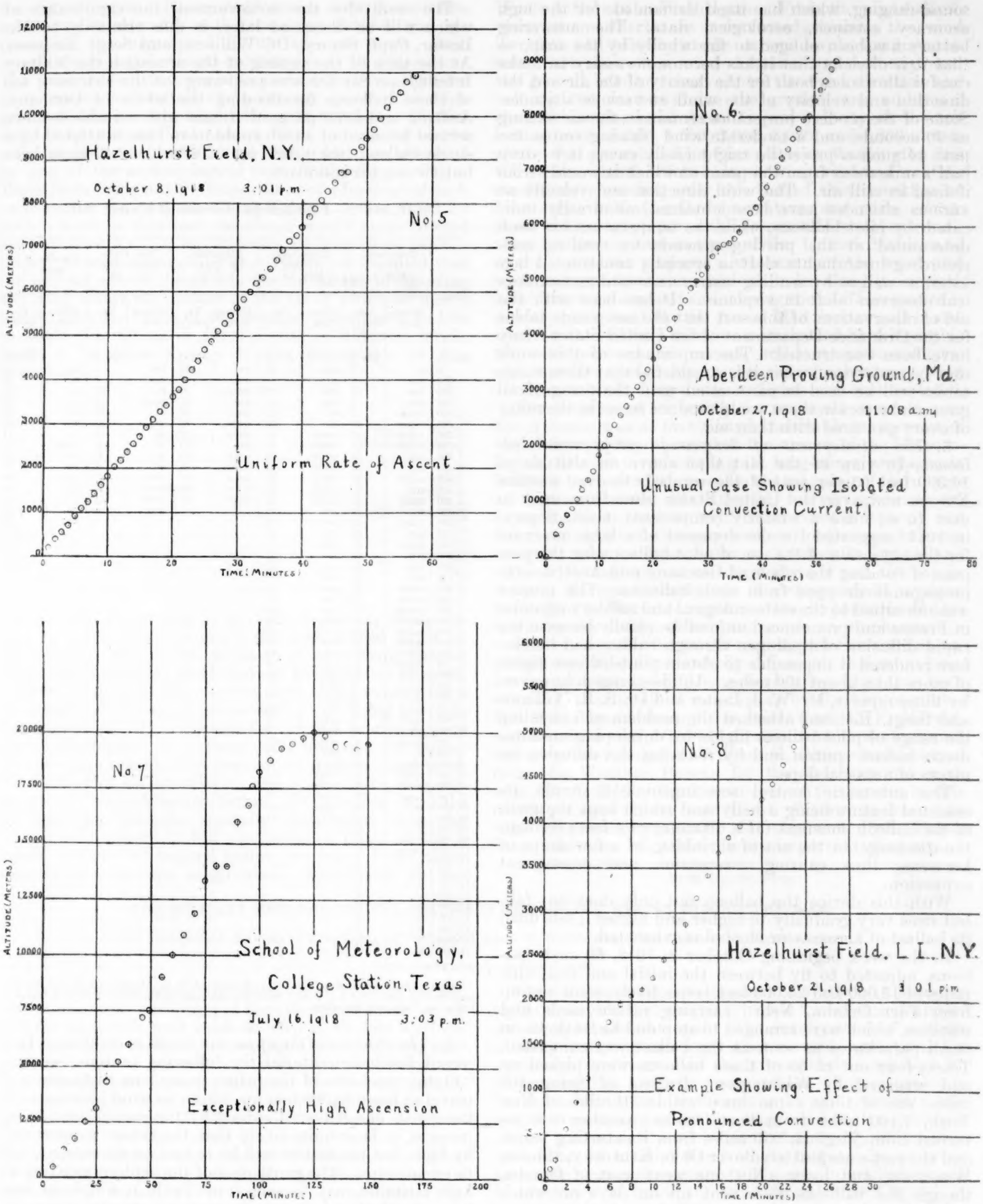


FIG. 2.—Time-altitude graphs of typical pilot balloon runs.

sound-ranging, which has itself demanded, for the high accuracy attained, aerological data. The answering battery has been obliged to fire wholly by the map, so that it is obvious that it has become necessary to make careful allowances both for the density of the air and the direction and velocity of the wind at various altitudes. Some of the modern projectiles remain in the air as long as 70 seconds, and a moderate wind blowing across the path of such a projectile might easily cause it to drop half a mile away from the point at which it would strike if fired in still air. The wind direction and velocity at various altitudes have been obtained, as already indicated, by pilot balloons, while the temperature has been determined at the proving grounds by sending self-recording instruments aloft in specially constructed box kites, as well as by sending instruments and meteorological observers aloft in airplanes. It has been with the aid of observations of this sort that the new range tables for the Ordnance Department of the United States Army have been constructed. The importance of this work may be understood when it is considered that these range tables will be used in connection with the firing of all guns, and errors in them would produce errors in the range of every gun fired with their aid.

3. *The development of long-range propaganda balloons.*—In view of the fact that above an altitude of 10,000 feet 95 per cent of the winds both over western Europe and over the United States blow from west to east (i. e., have a westerly component), Capt. Sherry, in 1917, suggested the development of a large program for the extension of the use of pilot balloons for the purpose of flooding the whole of Germany and Austria with propaganda dropped from such balloons. The project was submitted to the meteorological and military agencies in France and pronounced unfeasible, chiefly because the rapid diffusion of hydrogen through rubber had heretofore rendered it impossible to obtain pilot-balloon flights of more than about 100 miles. Undiscouraged, however, by those reports, Mr. W. J. Lester and Dr. S. R. Williams and Sergt. Redman attacked the problem of extending the range of pilot-balloon flights by developing an automatic ballast control and by reducing the diffusion by means of a special dope.

The automatic control was ingeniously simple, its essential feature being a bellyband which kept the girth of the balloon constant (at a diameter of 4 feet) through the discharge, in the act of shrinking, of a few drops of kerosene, thus causing reascension and consequent expansion.

With this device the balloon not only does not fall, but rises very gradually to higher and higher levels until its ballast of kerosene or alcohol is exhausted.

In the week beginning October 3, 1918, 60 such balloons, adjusted to fly between the initial and final altitudes of 15,000 and 25,000 feet, respectively, were sent up from Fort Omaha, Nebr., carrying return cards and watches, which were arranged to stop and be let down on small parachutes as soon as the ballast was exhausted. Thirty-four out of 60 of these balloons were picked up and returned to Washington. Instead of flying 100 miles, one of them came down within 10 miles of New York, 1,100 miles from Fort Omaha; another was returned from Virginia, 930 miles from its starting point; and the rest were scattered over Ohio, Kentucky, Illinois, Wisconsin, and Iowa. Not one went west of Omaha, though the balloons were sent up on days on which different surface conditions prevailed.

The credit for this achievement, the significance of which will be discussed later, is due primarily to Mr. Lester, Capt. Sherry, Dr. Williams, and Sergt. Redman. At the time of the signing of the armistice the Military Intelligence Service was preparing for the extensive use of these balloons for flooding the whole of Germany, Austria, and even parts of Russia with suitable leaflets, several hundred of which could have been scattered by a single balloon, the total cost of which would have been but two or three dollars.

TABLE 1.—*Pilot-balloon observations of wind, 1918.*

Altitude.	Groesbeck, Tex. Nov. 1.		Ellendale, N. Dak. Nov. 13.		Ellendale, N. Dak. Dec. 5.		Fort Oglethorpe, Ga. Nov. 29.		Mineola, N. Y. Sept. 7.	
	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.
Meters.		*Mis./h.*		*Mis./h*		*Mis./h.*		*Mis./h*		*Mis./h.*
0	e.	9	sw.	29	nw.	19	nw.	7	n.	18
250	ese.	16	s.	17	nw.	47	nw.	8	n.	51
500	ese.	13	sw.	16	nw.	49	nw.	11	n.	65
750	ese.	2	sw.	15	nw.	57	wnw.	19	n.	29
1,000	wsw.	5	w.	15	nw.	48	w.	29	w.	22
1,250	wnw.	11	w.	16	wnw.	49	w.	34	w.	20
1,500	wnw.	18	wnw.	18	wnw.	50	w.	36	w.	11
1,750	wnw.	23	wnw.	19	nw	64	w.	36	wsw.	13
2,000	nw.	25	wnw.	22	wnw.	68	w.	41	sw.	25
2,250	nw.	20	wnw.	25	wnw.	81	w.	46	sw.	47
2,500	wnw.	20	wnw.	27	wnw.	87	wsw.	47	sw.	63
2,750	nw.	23	wnw.	34	wnw.	96	wsw.	56	sw.	55
3,000	nnw.	21	wnw.	35	wnw.	93	wsw.	76	sw.	54
3,250	n.	18	nw.	35			wsw.	96	sw.	55
3,500	nnw.	29	nw.	40					sw.	81
3,750	nw.	25	nw.	41						
4,000	nnw.	20	nw.	41						
4,250	nw.	20	nw.	47						
4,500	nw.	21	nw.	53						
4,750	nw.	20	nw.	56						
5,000	wnw.	16	nw.	54						
5,250	wnw.	18	nw.	57						
5,500	wnw.	35	nw.	60						
5,750	wnw.	35	nw.	59						
6,000	wnw.	32	wnw.	63						
6,250	wnw.	25	nw.	69						
6,500	wnw.	26	nw.	68						
6,750	wnw.	25	nw.	68						
7,000	wnw.	19	nw.	74						
7,250	w.	8	nw.	77						
7,500	w.	12	nw.	85						
7,750	w.	9	nw.	65						
8,000	wsw.	4	nw.	73						
8,250	wsw.	16	nw.	76						
8,500	wnw.	20	nw.	69						
8,750	w.	22	nw.	75						
9,000	wsw.	20	nw.	73						
9,250	wsw.	20	wnw.	74						
9,500	wsw.	22	wnw.	68						
9,750	wsw.	28	wnw.	65						
10,000	w.	39	wnw.	78						
10,250	w.	47	nw.	81						
10,500	w.	50								
10,750	wnw.	59								
11,000	wnw.	57								
11,250	w.	44								
11,500	w.	39								
11,750	w.	41								
12,000	w.	47								
12,250	w.	51								
12,500	w.	56								
12,750	w.	59								
13,000	w.	60								
13,250	w.	64								

NOTE.—The flights of Nov. 1 and Nov. 15 began at 7 a. m., that of Nov. 29 at 7.39 a. m., and that of Dec. 15 at 8.26 a. m., 90th meridin time, while that of Sept. 7 began at 7.06 a. m., 75th meridian time.

4. *The charting of the upper air in aid of aviation.*—In a recent Brisbane editorial the following sentence occurs: "Flying machines of the future going long distances will travel at least 32,000 feet up, where no wind blows except the gentle eastern wind caused by the earth's motion on its axis." It is quite likely that the future aviator will fly high, but his motive will be to find an air current, not to escape one. The gentleness of the zephyrs existing at high altitudes may be seen from Table 1, which records five sets of pilot-balloon observations recently taken by

the Signal Corps. These observations show air currents increasing in intensity with increasing altitude and approaching the huge speed of 100 miles per hour. Such speeds are perhaps exceptional but not at all uncommon. The pilot balloon mentioned in section 3 above, traveled from Omaha to Virginia at an average speed of 30 miles per hour, the average height being 18,000 feet. On November 6, 1918, at Chattanooga, Tenn., a velocity of 154 miles an hour at an altitude of 28,000 feet was observed by one of the meteorological units of the Signal Corps. These facts bring out the importance of a forecast of such currents for the purpose of long flights. A flier aided by such a wind as that last mentioned would move toward his objective 2×154, or 308 miles an hour more rapidly than if he were opposed by it. When it is recalled that the aviator above the clouds has no means of knowing anything about the motion of the air in which he flies it will be seen that it is of the greatest importance to him to know the nature of the currents at different levels. Table 2 furnishes a very typical illustration of this importance.

TABLE 2.

Altitude.	Wind direction.	Wind. velocity.
Meters.		*Miles per hour.*
Surface	nw.	2.2
500	e.	5.8
1,000	e.	8.3
2,000	ne.	5.4
3,000	w.	5.4
4,000	nw.	24.6
12,000	nw.	49.2

From the above data it is evident that on this occasion an aviator flying toward the west should fly at an altitude of 1,000 meters, while an aviator flying toward the east should fly at an altitude of 4,000 meters or more.

In order to meet the obvious need of the aviator for a knowledge of the upper-air currents, the Signal Corps in the summer of 1917 undertook for the first time in history a general program of systematically mapping the upper-air currents of the United States, the Atlantic, and western Europe in aid of aviation and particularly with reference to trans-Atlantic flight. By the fall of 1918 26 upper-air stations carefully distributed over the United States were in full operation in place of the 1 station which had existed before the war. From these stations reports are telegraphed twice daily to the Weather Bureau in Washington. From the pilot-balloon observations charts are constructed showing the wind direction and velocity at the various levels; for instance, one chart shows the wind direction and velocity near the ground, another chart shows the wind direction and velocity 500 meters above the ground, and additional charts show the wind direction and velocity at the following levels: 1,000, 1,500, 2,000, 3,000, and 4,000 meters above the ground.[1] The forecaster at Washington has the various charts before him, showing wind and weather conditions prevailing over the United States, within an hour and a half after the observations are made. From these charts he prepares the forecast of weather conditions for the various sections of the United States, and at the same time prepares a statement of the wind and weather conditions at various altitudes along the various air routes for the use of aerial navigation. This service is already being used by the Aerial Mail Service. It is also used by the military fliers, as is evidenced by telegraphic requests received at various military meteorological stations for special reports on the weather and wind conditions when long-distance flights are contemplated.

The problem of exploring the upper-air currents over the Atlantic was at first thought insoluble on account of the absence of fixed bases, but the success of the Meteorological Service in developing its long-range propaganda balloons has now made possible the mapping of the upper-air highways across the Atlantic, for arrangements are being made to send up both from coastal stations and from trans-Atlantic steamers these long-range balloons designed now for from 2,000 to 3,000 mile flights, and adjusted to maintain a constant altitude and to drop in western Europe their records of average winds in these heretofore unchartable regions. The importance of this work for the future of aviation needs no emphasis.

The success which the Meteorological Service has attained would have been wholly impossible had it not been for the intimate and effective cooperation which has been extended to it in all of its projects by the United States Weather Bureau through its chief, Prof. C. F. Marvin, and its entire staff. The chief credit for the work abroad should go to Lieut. Col. William R. Blair, commissioned from the Weather Bureau for the observational work with the A. E. F. For the success of the service in this country Capt. Sherry and Lieut. Waterman have the chief responsibility. Capt. Murphy and Prof. Fassig have, however, contributed very important elements.

[1] See fig. 3, p. 220, below.

THE MILITARY METEOROLOGICAL SERVICE IN THE UNITED STATES DURING THE WAR.

By BERTRAM J. SHERRY, Captain, Signal Corps, and ALAN T. WATERMAN, First Lieutenant, Signal Corps.

[Dated: Washington, D. C., May 15, 1919.]

Previous to the beginning of the war in 1914 no nation, with the possible exception of Germany, had made provision for meteorological work as used in modern warfare. It is true that surface meteorological observations were made at some of the military posts, but no systematic meteorological work was attempted nor had any upper-air observations been made with a view to providing the Air Service and the Artillery with necessary meteorological data. In the United States the Weather Bureau has always maintained an efficient civilian meteorological service and has accumulated an enormous amount of data, both of surface and of upper-air meteorological conditions, and had not these data been available during the war a great many aviation and artillery problems would have been much more difficult.

With the present development of aviation it becomes highly desirable that a more intimate knowledge of upper-air conditions be obtained. The development of modern artillery makes it necessary that certain corrections for variation from normal in the atmospheric conditions be incorporated in artillery range tables. For instance, it has been found that in firing the 75-mm. gun at a target 7,000 meters away an opposing wind of 10 meters per second will cause the projectile to fall nearly 400 meters (a quarter of a mile) short of the target. In order to make the proper correction to the aim in artillery fire it is necessary to know the wind direction and speed at various altitudes up to the maximum height reached by the projectile. In the case cited above this would be approximately 2,000 meters. Besides making corrections

for wind, it is necessary also to make allowance for variations in the density of the air, and in some instances this correction is quite as important as that for wind. The use of gas in the war made it important that close attention be paid to wind direction and speed. In fact, the operations of all branches of the military service were to a considerable extent dependent upon weather conditions, and consequently weather forecasts were in demand.

It was some time after the declaration of war before England and France had meteorological services operating with their armies.[1] When the United States entered the war a few months elapsed before it was decided that the United States would put a large army on the battle front. When it became evident that such an army would be sent to Europe it was also apparent that a military meteorological service would be necessary as a part of this army. The Chief Signal Officer of the Army directed that a Meteorological Service be organized within the Signal Corps, under the immediate supervision of Lieut. Col. R. A. Millikan, Chief of the Science and Research Division of the Signal Corps. Dr. W. R. Blair and Mr. E. H. Bowie, both of the U. S. Weather Bureau, were commissioned as majors in the Signal Corps and sent overseas to investigate and report on the needs of the American Expeditionary Army for meteorological data. It was the intention at first to provide a meteorological service for duty with the American Expeditionary Forces only. However, it was soon found that it would be necessary to organize a meteorological section for duty in the United States to furnish data to the various military posts for the benefit of Ordnance, Air Service, and Artillery units in training, and in the development of problems in connection with their work. From cablegrams received from Gen. Pershing it was determined that approximately 21 officers and 300 enlisted men would be required for duty overseas. Approximately 15 officers and 200 men were required to meet the needs for military meteorological work in the United States.

The number of men with the qualifications desired was not available, and it was necessary to take men having satisfactory educational qualifications and give them additional training in meteorology and aerology. The first 150 men obtained were sent to various Weather Bureau stations in the United States for training in meteorology. After a short period of training nine of these men were sent to Fort Omaha, and in November, 1917, the first military meteorological and aerological station was established at that place. A school of meteorology was opened at College Station, Tex., with Dr. Oliver L. Fassig as Chief Instructor, where approximately 330 men were given training in meteorology and aerology.[2] Men were sent overseas in groups of 50 until approximately 300 men had been sent.

In the United States 37 military meteorological stations were established, equipped with instruments and personnel for furnishing meteorological data to other branches of the Army. Most of these stations were at military posts and were established at the request of some branch of the military service. The stations at the Aberdeen Proving Ground, Aberdeen, Md., and at the Sandy Hook Proving Ground, Sandy Hook, N. J., were established for furnishing accurate data of surface and upper-air conditions to the Ordnance for use in connection with range-firing experiments. At both of these stations the Meteorological Section of the Signal Corps cooperated with the Ordnance in developing the first range tables constructed by the United States Army in which corrections were to be incorporated based on actual observations for variations from normal air density, wind direction, and speed along the trajectories. For the purpose of instructing student officers and men in the use of these tables, military meteorological stations were established at the Coast Artillery School, Fort Monroe, Va., the School of Fire, Fort Sill, Okla., and the Field Artillery Firing Centers at Camp Jackson, S. C., and Camp Knox, Ky. Meteorological stations were also established at Hazelhurst Field, N. Y.; Ellington Field, Tex.; Kelly Field, Tex., and a number of other flying fields in various parts of the country, for the purpose of supplying information concerning both surface and upper-air conditions for use in connection with the training of student aviators and also in connection with cross-country flying. For the purpose of furnishing meteorological data to be used in connection with the training of balloon pilots and observers for both observation and free-balloon work, stations were established at the Army Balloon Schools at Fort Omaha, Nebr., and Arcadia, Cal. Meteorological stations were established at a number of other points in the United States for the purpose of furnishing data to other branches of the Army, and many of the stations, including some of those named above, furnished data to two or more branches of the military service.

In organizing the Meteorological Service the Signal Corps was confronted with the project of creating what was in many respects an entirely new service for the Army designed to supply the military organization with complete and up-to-date meteorological information, and this as promptly and efficiently as possible. The undertaking necessarily involved, in addition to consideration of methods employed by former or present meteorological organizations, actual experimental investigation, and the development and standardization of new methods. Inasmuch as the U. S. Weather Bureau constituted an efficient organization for dealing with surface meteorological data, and as a number of the personnel of that department were available for the Service and familiar with its methods, it was decided, as far as surface observations were concerned, to adopt as standard practice the methods and type of equipment used by the Weather Bureau.

The question of the proper units to be employed in recording observations and in issuing reports required consideration, and the metric system was decided upon as being the simplest and also that required for work overseas. For serving the various military branches in the United States, however, a number of different units were in use, so that it was impracticable to adopt a single system which would conform to all requirements. In this country, therefore, observations were recorded and station records were kept in the metric system, and reports were furnished in any units desired locally.

The main outstanding problem was that of developing suitable methods for obtaining data concerning the upper air. The methods which had previously been employed for this purpose were: (1) The use of sounding balloons, (2) manned (free) balloons, (3) observation (kite) balloons, (4) kites, and (5) airplanes. All of these permit the procuring of complete upper-air data (temperature, pressure, humidity, and wind). The sounding-balloon method consists of attaching recording apparatus to a balloon of approximately 7 feet diameter

[1] For an account of the British service, see "Meteorology during and after the war," MONTHLY WEATHER REVIEW, February, 1919, 47:81-83.

[2] See "A Signal Corps school of meteorology," by O. L. Fassig, MONTHLY WEATHER REVIEW, December, 1918, 46: 560-562. Some account of the methods of teaching at this school are given in "Collegiate instruction in meteorology," by C. F. Brooks, ibid., pp. 554-560.

inflated with hydrogen and allowed to ascend. When the balloon bursts or loses its gas the apparatus descends on a parachute. For military purposes, the sounding balloon is evidently out of the question on account of the delay and uncertainty in recovering the recorded data. The manned balloon is debarred for the same reason, and also because of the limited range of observation. Observation or kite balloons may, of course, be employed. There are serious limitations to their use, however, such as the expensive and elaborate equipment, the low altitudes attained, and the danger in launching in a high wind. Kites are excellent, but require considerable equipment, and render aviation unsafe in their neighborhood on account of the kite wire. They also are not readily launched in very light winds. Nevertheless, they are desirable equipment for permanent meteorological stations where accurate and complete data aloft are required. The last-named method, by airplane, is entirely practicable and has been employed by the Signal Corps at the Aberdeen Proving Ground. Recording apparatus is carried by the airplane, which flies steadily for a certain length of time at each altitude for which data are desired. An alternative, and the usual method, is to carry non-recording instruments, which are read by an observer at the altitudes desired, and whenever any unusual condition is experienced. The use of an airplane for obtaining data aloft has the disadvantage that it is impracticable to determine the wind velocity accurately. More than 350 airplane meteorological flights have been made at Aberdeen, usually to 10,000 feet.

Such complete knowledge of upper-air conditions as will admit of the computation of densities aloft is desired by the Artillery only, whereas a knowledge of the wind aloft is extremely valuable to the aviation and balloon services as well as to the Artillery. There are several simpler methods available for ascertaining only wind speed and direction: (1) Observations on pilot balloons, (2) observations on movement of the smoke of anti-aircraft shell bursts, and (3) sound-ranging on pilot balloons carrying a train of explosives.[3] Inasmuch as a knowledge of the upper winds is what is mainly desired by the Army, the development of efficient methods for obtaining these data was of foremost importance. Since the two latter methods mentioned depend upon the assistance of two other branches of the Army—the anti-aircraft and the sound-ranging services—it was decided to use the first, namely, that by observation on pilot balloons. This method was soon found to be most satisfactory, and, accordingly, an important undertaking of the Signal Corps was the development of practicable, speedy, and efficient means of making upper-air observations with pilot balloons, and of computing and tabulating therefrom data in a usable form. Practicable field methods were soon devised, and these have continually been improved until at the present time a highly efficient system is in operation. The disadvantage of the pilot-balloon method of observation is the fact that the observation is limited to the height to which the balloon can be seen, and is therefore restricted in altitude on cloudy days. On clear days, however, it is far more efficient than other methods, as is evidenced by the fact that observations to a height of about 12 kilometers are by no means unusual. The record altitude reached in this service by this means is 20 kilometers,[4] and balloons have been seen to a horizontal distance of 70 kilometers.

Although the pilot-balloon method of determining wind aloft was not new to meteorologists, it had only been applied in connection with upper-air research, in which the speed of computing results and the transfer of the equipment was of secondary importance. The Signal Corps immediately undertook the development of practicable military methods, which require principally speed of operation and portability of equipment. Briefly, the operation consists in allowing a pilot balloon to ascend freely. The balloon in its upward course is carried along horizontally by the wind and is a most sensitive indicator of wind velocity. It may be viewed through two theodolites placed at the ends of a measured base line, and simultaneous reading of elevation and azimuth angles may be made at regular intervals. By triangulation the actual path of the balloon relative to the earth may be calculated. From the horizontal projection of this path, which is plotted for points taken at known intervals of time, the average wind velocity (speed and direction) over any interval may be obtained at each respective altitude. An alternative method, which is more easily adapted to military use, employs only one theodolite, and assumes a known uniform rate of ascent of the balloon. The computation can then be made as before, much saving is effected in personnel, equipment, and portability, and the method is admirably adapted to rapid field work.

A requirement for either the one or the two theodolite method is a satisfactory type of balloon. The balloon should admit of high inflation and possess minimum weight in order to reach the greatest possible altitude before being lost to sight. The rubber should be so cured as to retain its elasticity for a moderate period, should allow only slow diffusion of hydrogen through its walls, and should be so colored as to be visible against the different backgrounds encountered. All balloons should be of the same shape in order to simplify the calculation of rate of ascent. Much attention has been given to these points, and after careful testing it has been found that the most satisfactory balloons are of pure rubber, and of approximately spherical shape when inflated. (See frontispiece.) These balloons are used in two shades—uncolored, for use against a clear sky, and dark red, for a cloudy or hazy sky. A balloon which will inflate to a maximum diameter of 80 centimeters should weigh from 20 to 30 grams, and one inflating to a maximum diameter of 120 centimeters, approximately 50 to 60 grams. The manufacture of satisfactory balloons of larger size than the last named (about 9 inches in diameter deflated) appears to be very difficult.

A special type of theodolite (see fig. 3, opposite p. 207) was designed by Dr. W. R. Blair while connected with the U. S. Weather Bureau. This instrument, with a few minor alterations, has been used exclusively in this country. Its essential feature is the use of a right-angled prism at the center of the telescope tube, whereby the observer is able to look always in a horizontal plane while sighting upon objects in space.

Although the single-theodolite method of observation is more readily adaptable for field use than the two-theodolite method, the accuracy of its results is dependent upon the accuracy with which the altitude of the balloon is known. With the formulas for rate of ascent now in use this accuracy is not great. It was therefore found desirable to maintain meteorological stations for two-theodolite observations at posts where the greatest degree of accuracy was desired, as, for instance, at proving grounds where investigations were conducted concerning the factors which influence the flight of projectiles. Considerable work was necessary in order to bring this more cumbersome method to a point where

[3] For further details see MONTHLY WEATHER REVIEW, Feb., 1919, 47: 70.
[4] See graph No. 7 in fig. 2, p. 213, above

the necessary speed of operation would be attained. A large number of devices were designed to gain this end. Special slide rules and alignment charts have been made for solving the trigonometric formulas involved in determining the position of the balloon from time to time. After the latter is known the path of the balloon may be readily plotted and the wind velocity obtained at any altitude. Methods have been devised for computing the wind velocity without graphical aid, but they have been found not to compare favorably with graphical methods.

These latter methods operate on the principle of duplicating on a small scale the configuration of the system (balloon, base line, and two theodolites) by means of plotting board and apparatus. For finding the altitude of the balloon when the horizontal projection path is known, an ordinary slide rule may be used, or this, too, may be solved by graphical means. Plotting boards for two-theodolite work, differing slightly in detail, were developed independently at Signal Corps stations at Aberdeen Proving Ground, Fort Monroe, Fort Sill, Hazelhurst Field, and Ellington Field. A form which seems to be as direct as any that can be devised is illustrated and discussed on page 222 below. It is necessary for rapid work that telephonic communications be established between the observing stations and the plotting room. Each observer and each plotter wears a telephone head set. (Fg. 1, frontispiece.) The readings are called in from the observing stations to the plotting room as soon as taken; thus the charting goes on as fast as the observation progresses. To insure simultaneous readings, at each of the two theodolites suitable signals are given the observers by means of a standard Signal Corps time-interval apparatus and time-interval bells, or these signals may be sent by means of a buzzer on the telephone circuit. In this way the computation of the wind velocity may be made to keep pace with the observation. The two-theodolite method of observation is, of necessity, available for use at more or less permanent stations only.

In regard to the simpler, single-theodolite method, the first requisite was a formula for the rate of ascent of the balloon in order that the altitude might be known at each reading taken. In other words, it was necessary to predict from known measurements of a given balloon, as, for instance, its diameter, weight, and lifting power, what the rate of ascent would be. Some general deductions regarding the rate of ascent of pilot balloons have been given by Mallock[5] from theoretical considerations. In his paper it is shown that at first, leaving out of consideration the loss of gas, a balloon will ascend with a slight positive acceleration, which later decreases to zero and then becomes increasingly negative until the maximum altitude is reached. This behavior is exhibited to some extent by large sounding balloons; but they are inflated to a much less degree than the small pilot balloons in the attempt to reach high altitude rather than to gain a rapid ascensional rate. As a matter of fact, practically all the pilot-balloon observations of the sort conducted by the Signal Corps show a rate of ascent which is very nearly uniform up to altitudes of certainly 10 kilometers and in many cases much higher. The matter of the rate of ascent is also treated by Millikan[6] and, as shown by him, for moderate altitudes the loss of gas by diffusion just compensates for the positive acceleration that would otherwise occur.

[5] A. Mallock: Proc. Roy. Soc. v. 80, No. A541, June 10, 1908, pp. 530–534.
[6] R. A. Millikan: p. 211, above.

This fact has been taken advantage of in most work that has been done on the rate of ascent of pilot balloons to deduce a partially theoretical formula, which will satisfy experimental results. It is assumed that since the rate of ascent is constant a formula will apply which holds for the case of a balloon moving through air of constant density and under the influence of a force equal to its lifting power in such an atmosphere. To enter into the subject fully would properly require a special article. It may be stated briefly, however, that the two best known formulas derived in this way are those of Dines[7] and Hergesell.[8] They are respectively:

$$V = K\frac{l^{1/2}}{L^{1/3}};\quad V = f\left(\frac{l}{L^{2/3} - 0.8L^{4/3}}\right)$$

where V represents velocity; l, the "free lift," represents the actual lifting power of the balloon, i. e., the attached weight it will support; L, "the total lift," is the free lift plus the weight of the balloon; and K is a constant. Variations in density of the air introduce negligible errors in comparison with those due to other causes.

A large amount of investigation has been conducted by the Meteorological Section, Signal Corps, with a view to solving this problem. At the beginning it was found that the formulas of Dines and Hergesell did not agree with actual free-air observations made by the Signal Corps, and at Fort Omaha in December, 1917, a purely empirical formula was deduced, which was used for a short time. Its use is restricted to balloons of total lift in the neighborhood of 80 grams only, and it is accurate for the range for which it was designed. It was soon discarded, however, on account of its restricted range and applicability to balloons of low inflation only.

From the records of about 5,000 pilot-balloon observations made with two theodolites at various points in the United States, 1,000 have been selected because of their length and accuracy. These have been tabulated and examined carefully. It is found that the results obtained do not agree with the results of either Dines or Hergesell for the type of balloons employed. In addition, experiments in charge of Lieuts. W. S. Bowen and H. H. Anderson were performed at the Signal Corps School of Meteorology, College Station, Tex., in which balloons of various diameters with different weights attached were dropped from the interior dome of a high building and the rate of descent directly observed. On the basis of these experiments and the accumulated data obtained from two theodolite observations mentioned above the following formula was produced:

$$V = 71\left(\frac{l}{L^{2/3}}\right)^{5/8} = 71\left(\frac{l^3}{L^2}\right)^{.208}$$

The accuracy of any formula yet devised leaves much to be desired, as the velocity of ascent may be relied upon only to an accuracy of 5 per cent or occasionally 10 per cent. The formula developed by the Signal Corps has been demonstrated to be more accurate for the work in hand than that of either Dines or Hergesell.

Tests on the internal pressure of balloons used show that it at first decreases with increasing inflation, later becomes very nearly constant (approximately 5 cm. of water) for a considerable range, and increases just before

[7] Quart. Jour. Roy., Meteor. Soc. April, 1913, v. 39, pp. 101–107, and April, 1918, v. 44, pp. 131–133.
[8] Sixième Réunion de la Commission International pour l'Aerostation Scientifique, Monaco, 1909, pp. 86–103.

the bursting point is reached. The diffusion through the walls is rather an uncertain quantity, but averages about 4 to 6 per cent of the volume per hour.

To return to a discussion of the single-theodolite method of observation, where it is assumed that the altitude of the balloon at the time of taking each reading is known beforehand, and the only remaining quantity to be determined is the radial distance in a horizontal plane of the balloon from the starting point. This permits of ready calculation with an ordinary slide rule on account of the simple formula involved, viz:

$$\text{Distance} = \text{height}/\tan e;$$

where e is the elevation angle.

One successful method for single-theodolite work is to compute this horizontal distance by slide rule and then to chart the balloon's path on a simple plotting board provided with a scaled arm pivoted at the center of a 360° protractor. Another satisfactory method consists in the use of a similar board combined with a graphical altitude-finding device, the principle of which is the graphical solution of the above formula. Fully a dozen efficient plotting boards and methods have been devised by members of the Meteorological Section of the Signal Corps, which differ in details of construction but which fall under one of the two general classifications named above. That adopted by the Meteorological Service for general use is illustrated in figure 4. The observation point should be connected by telephone with the plotting room as in two-theodolite work and the time-interval system is also an advantage, though not essential.

An important feature of the meteorological work at Artillery stations consists in the calculation of the "ballistic" wind. Corrections for Artillery fire are made for variations of meteorological conditions from normal. The normal condition as to wind is taken by the Artillery to be "calm." Since the wind differs in speed and direction at different altitudes and since a projectile spends a different amount of time in each zone of altitude, it is necessary that these factors be taken into consideration. The "ballistic" wind is an imaginary wind, which would have the same deflective effect upon a given projectile as the total resultant effect of the varying winds which the projectile encounters during its flight. A projectile spends an increasing amount of time in each successive zone up to the maximum ordinate; in fact, about half the time of flight is spent above three-fourths of the maximum ordinate. The ballistic wind is, therefore, computed by finding the resultant of the true wind velocities for zones of equal altitude up to the height of the maximum ordinate, each taken with properly applied weighting factors. At Artillery and Ordnance stations the meteorological detachments are expected to compute this ballistic wind in connection with all balloon observations. Considerable work is here involved since, as a rule, a ballistic wind must be calculated for each different maximum ordinate; thus, frequently, from a single balloon observation the ballistic winds for 10 different maximum ordinates are required. Methods of calculation are in use in Signal Corps meteorological detachments which enable reports to be delivered on these ballistic winds at the completion of the balloon observation. In addition to the work of computing these data at all Artillery posts, at the Aberdeen and the Sandy Hook Proving Grounds meteorological detachments under the direction of Lieut. J. W. Howard, Signal Corps. cooperated with the Ordnance Department in examining the results of range firing under different meteorological conditions and in devising means of making the proper corrections.

A great variety of problems were undertaken by the Signal Corps, a number of which are briefly outlined below.

Upper-air data obtained by making simultaneous observations at Signal Corps stations in various parts of the country are telegraphed to the United States Weather Bureau at Washington, where upper-air forecasts are issued daily by the Weather Bureau regarding upper-air conditions likely to be encountered in flying over various parts of the United States. This work gives promise of being, in addition to its military value, of material assistance to the Aerial Mail Service and commercial aviation in the United States. Charts of winds at different levels above the surface over the United States, as observed on February 5, 1919, are shown in figure 3. For dynamical studies this usual method of mapping according to altitude above the observation point, gives way to that of mapping according to altitude above sea level.[9] In fact, for long distance flights, maps of this latter type are more useful to aviators than are those shown in figure 4, for the atmospheric pressure, rather than the configuration of the surface indicates (by altimeter) the elevation.

The question arose as to the area over which the results of a wind-aloft observation might be expected to hold. Although it was known that the upper winds are practically constant for a considerable range and that this is not true of the surface wind, an actual series of tests were conducted at Sandy Hook and at Aberdeen. Single theodolite observations were made simultaneously at Sandy Hook Proving Ground and at Long Branch, N. J., which are approximately 25 miles apart. Simultaneous observations were also made with two theodolites each at Aberdeen and Swan Point, Md., 26 miles apart, at opposite ends of the proving grounds. More than 100 observations were taken, and from the results it appears that between the stations at either proving ground the differences in the wind velocity at the same levels above altitudes of 500 to 1,000 meters were, almost without exception, less than 4 per cent. It was, therefore, concluded that the result of the wind-aloft determinations, can be relied upon usually for practically every purpose within a radius of 25 miles.[10]

A detail that was studied with interest was the effect of vertical convection currents upon the balloon as showing the magnitude of such currents and the height to which they are likely to ascend. Lieut. Tannehill has discussed some instances on pages 223–225, below. It was found that such currents are apt to exist from the ground to an altitude of about 1,000 meters, decreasing in intensity with altitude. As a general thing, during the daytime the balloon's rate of ascent is likely to be accelerated about 20 per cent for the first 300 to 400 meters of ascent, and then often diminished for the succeeding 100 meters, after which it becomes constant. More rarely the reverse is true, the balloon rising less rapidly at the start. Occasionally, pronounced convection is evident up to 3 kilometers, and at times indications of strong isolated ascending or descending currents may be found at altitudes up to 10 kilometers.

At the Signal Corps stations at the Army Balloon Schools at Fort Omaha and Arcadia, systematic observations from kite balloons were made on the visibility possible in different conditions of the atmosphere.

[9] Cf. Daily Weather Report, Upper-Air Supplement, Metl. Off., London: Morning, afternoon, and evening wind maps are published daily (since Apr. 1, 1919) for the surface, 1,000, 2,000, 5,000, 8,000, 10,000, 15,000 feet and upper-cloud, and lower-cloud levels.—ED.

[10] Such is not the case, however, with data *below* 500 meters at Coast Artillery stations, as indicated by Col. W. E. Ellis in discussing "Free-air data in the Hawaiian Islands, July, 1915" (MONTHLY WEATHER REVIEW, 1917, 45:52–55). Experiments with 12-in. shells indicated that weather conditions at the battery a little way inland do not show the conditions on the coast or out to sea.—ED.

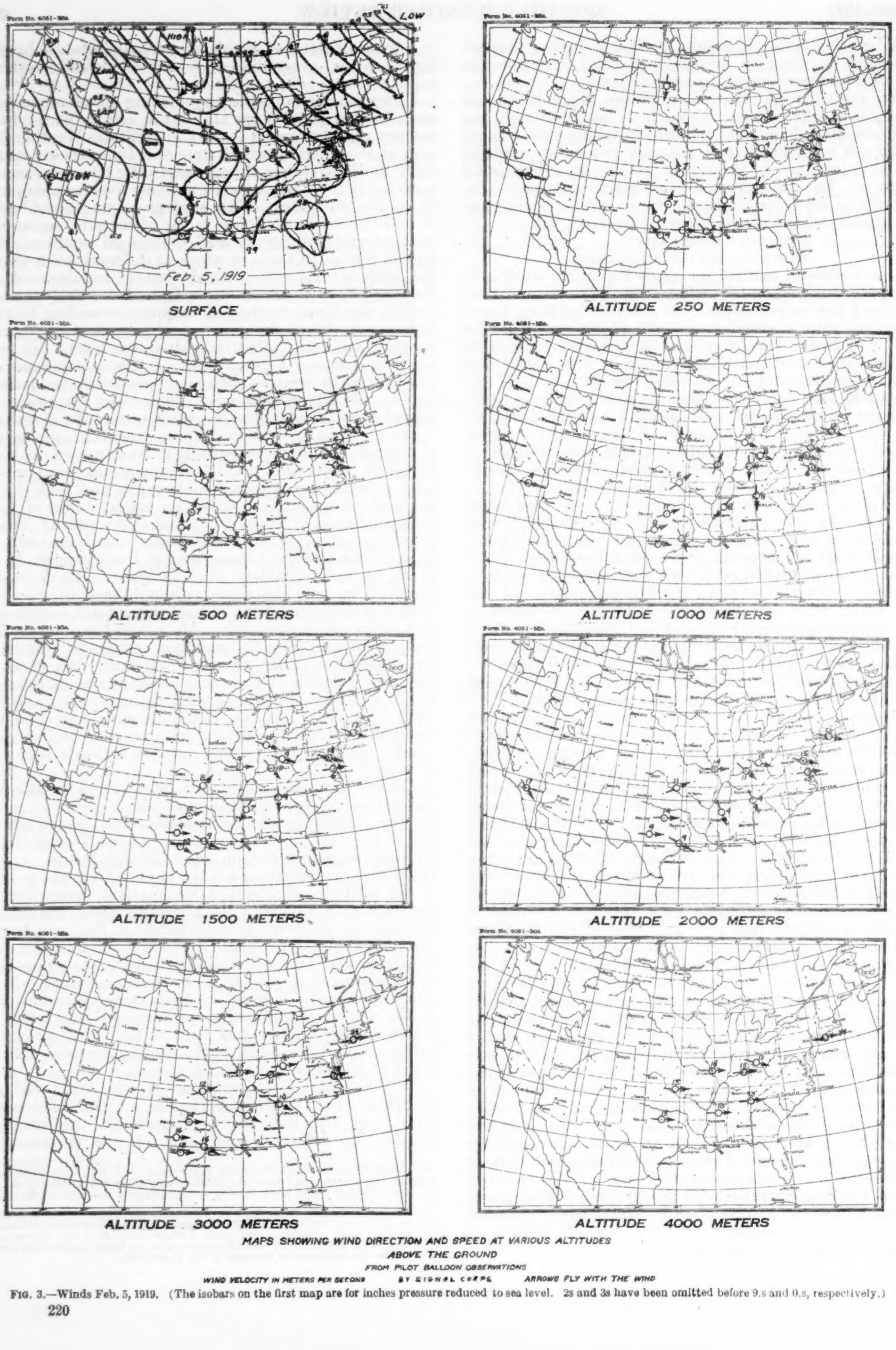


FIG. 3.—Winds Feb. 5, 1919. (The isobars on the first map are for inches pressure reduced to sea level. 2s and 3s have been omitted before 9.s and 0.s, respectively.)

Visibility charts were made twice daily showing (1) the extreme limit of vision, (2) and the limit of clear vision, in every direction from the observation point.

The question of night pilot-balloon observations was investigated at a number of stations. The various methods that have been employed to render the balloon visible at night are: (1) The suspension from the balloon of a small test tube filled with kerosene into the stopper of which a lamp wick is inserted, (2) a ball of tow bound with wire and saturated with kerosene, (3) a small electric flash light, (4) luminous paint, and (5) a small box constructed of tracing cloth containing a candle. In such devices the fire risk must be taken into account, in case the balloon bursts at a low altitude. The method used overseas was the last one named, i. e., the candle in a tracing cloth box, and this far it seems to be the most satisfactory method.

At Ellington Field, Tex., in cooperation with the Weather Bureau and the Engineer Corps, kite equipment was utilized to raise to altitudes of about 1,500 feet listening devices for detecting the approach of airplanes.

A large variety of charts and tables have been made for calculation of vapor pressure, relative humidity, dewpoint, air density, temperature correction for barometer, wind velocity from chart of balloon's course, rate of ascent of pilot balloons, ballistic wind, etc.

The methods in use for pilot-balloon work have been analyzed and studied, especially in regard to their degree of accuracy. In this connection, the following is of interest: For two-theodolite work a suitable plotting board will give results as accurate as the readings of the theodolites. For the altitudes and distances ordinarily reached in pilot-balloon work and with the present type of theodolite the most satisfactory length of base line is about 2,000 meters. When only two instruments are employed the general formulas for trignometric calculation of the balloon's position are:

$$d=\frac{b\sin B}{\sin(A-B)};\ h=d\tan e \qquad (A)$$

where d equals horizontal distance from observation point (1).

h equals altitude above observation point (1).
b equals length of base line.
A equals azimuth angle at observation point (1).
B equals azimuth angle at observation point (2).
e equals elevation angle at observation point (1).
e' equals elevation angle at observation point (2).

Both instruments are set with zero azimuth along the base line and in the same direction.

This formula is impracticable when the balloon is nearly in a vertical plane through the base line, as the azimuth angles can not then be read with enough accuracy to avoid large errors in the calculation. In this case, the following formula gives more satisfactory results when the observing stations are at approximately the same altitude:

$$h=\frac{b\tan e\tan e'}{\sqrt{\tan^2 e-\sin^2 A\tan^2 e'}\ \pm\mathrm{Co}^*\mathrm{s}\,A\tan e'}$$

A more usable approximation of the latter formula is:

$$h=\frac{b\tan e\tan e'}{\tan e\ \pm^*\tan e'}$$

* The plus sign is used when the balloon is between the observing points; otherwise the minus sign is employed.

This latter formula is sufficiently accurate for azimuth angles less than 10° or 12°, which is the range at which formula (A) begins to break down. The difficulty observed in the use of formula (A) is also found in the use of a double-theodolite plotting board such as described, and in such a case it is customary to assume that the balloon is in a vertical plane through the base line and to use the two plotting arms for finding the horizontal distance and altitude by duplicating the base line and two elevation angles, rather than the two azimuth angles.

The accuracy of the single-theodolite method is only as good as the closeness with which the rate of ascent is known, and this is almost always within 5 per cent. The effect on the wind aloft is roughly within an error of 5 per cent in the wind speed and the same error in the altitude for which the direction and speed are given. One precaution should be stated here; it sometimes happens that a balloon springs a leak at a certain altitude, and this may cause it to start descending instead of rising at the assumed rate. (See graph 7, fig. 2, p. 213, above.) Since this may not be directly detected by a single theodolite the effect is apparently to increase the distance of the balloon from the instrument, and this in turn magnifies the computed velocity. Therefore, when the single-theodolite method is employed, especial care should be paid to using only very perfect balloons and to see that the neck is sealed tightly before releasing.

A further precaution in the use of balloons is to allow them to stand for a time outdoors subject to current conditions of sun and air, etc., before taking measurements of them, as it has been found that the temperature of a balloon exposed to the sun may be as much as 10° to 20° C. above that of the surrounding air. This causes considerable increase in its size and, therefore, in its lifting power.

In regard to the organization of the military work and the standard methods of operation, it has been found advisable to separate the meteorological stations into two classes— (1) meteorological units for surface data, and (2) aerological units for upper-air data. Meteorological units are further subdivided into those of the first and of the second orders. A first-order meteorological unit is provided with complete meteorological equipment such as is found at regular stations of the U. S. Weather Bureau and is intended to be used at a more or less permanent station only. A second-order meteorological unit possesses only a limited amount of recording apparatus and emphasis is laid upon the portability of the equipment. In like manner, aerological units are divided into two orders—first-order units for two-theodolite work and intended for duty at more or less permanent stations, and second-order units with portable equipment for single-theodolite work. In actual practice combinations of these units are employed, as, for instance, a first-order aerological unit and a first-order meteorological unit are assigned to a permanent station which is to furnish complete data, and aerological and meteorological units both of the second order are assigned to duty at mobile field stations.

For the surface meteorological work the equipment used is all of standard Weather Bureau type, and the forms in use are similar to the corresponding Weather Bureau forms. For aerological work the standard equipment consists of special aircraft theodolites and pilot balloons, as already described. Hydrogen of good purity is used, furnished in steel cylinders having a capacity of 200 cubic

feet of gas at a pressure of 1,800 pounds per square inch. For obtaining the lifting power of the pilot balloon, an ordinary balance or scale pan with a set of metric weights is used at permanent stations for accurate work; for a portable field outfit a bronze chain is used with auxiliary weights. The chain is tied to the balloon and from the number of links supported the lifting power is obtained. For single-theodolite work a standard plotting board is employed, the idea of which was originally due to Sergt. 1st cl., E. R. Ryder, Signal Corps. It consists of a transparent celluloid protractor, whose surface is roughened in order to take a pencil mark, which revolves about a pivot in a board covered with cross-section paper. The board is illustrated in figure 4. The method of operation is as follows: By rotating the celluloid protractor, set the azimuth angle for the given reading on the scaled reference line O M; set the arm O R at the elevation angle read on the quadrant protractor on the cross-section paper; find the intersection of the altitude cross-section line (as read on the altitude reference line O N) with the arm O R and follow along the perpendicular cross-section line to the reference line O M and mark the point. This point is the horizontal projection of the location of the balloon for the given reading and the horizontal distance from start may be read from the scaled reference line if desired. This process is repeated for each reading and results in a series of points which determine the horizontal projection of the balloon's path. To obtain the mean wind direction between any two points, set the two points in question so that they lie along the cross-section lines parallel to the reference O M; the direction from which the wind blows is read at P in the units desired. The wind speed may most conveniently be measured by means of a special scale which reads the velocity directly in the units desired. The standard type of two-theodolite boards is an adapted form of this single board and possesses all its advantages. (See figure and discussion, by W. C. Haines and R. A. Wells, below.) Ballistic wind plotting may also be done on the same board at the same time in any convenient portion not in use for plotting the balloon's course.

Meteorological observations on surface conditions are taken at 8 a. m. and 8 p. m., 75th meridian time, and at 12 noon, local time, and whenever balloon ascensions are made. Standard Weather Bureau practice is followed in the procedure. Cloudiness observations are made every two hours from 6 a. m. to 10 p. m. Regular balloon observations are made at 8 a. m. and 4 p. m., 75th meridian time, and whenever locally desired. When continuous reports on the wind aloft are required observations are made every three or four hours. Observations of other character are made whenever desired by departments of the local posts.

All of the meteorological work of the Army has been done in the closest cooperation with the U. S. Weather Bureau. The Weather Bureau furnished all the instrumental equipment used by the Military Meteorological Service during the first few months, and the resources of the Weather Bureau and the counsel of the Chief of the Weather Bureau and his staff have always been available to the Meteorological Section of the Signal Corps and these have been used freely. Without this assistance from the Weather Bureau the early accomplishments of the Military Meteorological Service in the United States would have been of little consequence.

The Meteorological Section of the Signal Corps was under the general supervision of Lieut. Col. R. A. Millikan from the beginning of its organization, during the war, and to December 31, 1918, and under the general supervision of Lieut. Col. John C. Moore since that date.

Much credit is due the enlisted personnel for the work accomplished. Many of these men left responsible positions to become privates in the Meteorological Service. These men not only performed faithfully the work laid out for them to do, but developed new methods and devices for doing the work. It is impracticable to mention individuals by name, because of the large number of men in the service who have accomplished work that would make them worthy of commendation. The personnel was made up mostly of graduate engineers, physicists, mathematicians, and employees of the Weather Bureau.

It should be noted that no mention is made here of the meteorological work done at the actual battle front in France. The Meteorological Section of the Signal Corps had, however, about 15 officers and approximately 300 enlisted men all trained in meteorology and aerology at the front, and it is thought best that the description of the accomplishments of this portion of the Meteorological Section be left to those who have been engaged in the work overseas.[11]

TWO-THEODOLITE PLOTTING BOARD.

By W. C. HAINES and R. A. WELLS.

[Dated: Weather Bureau, Washington, D. C., May, 1919.]

This board (fig. 1) is identical with the one-theodolite board that is now being used in the Weather Bureau (essentially, that shown in fig. 4 opp. page 222), with the additional features of (1) a protractor, centered at B, and (2) an elevation scale, CD, both drawn on the cross-section paper base, and (3) a brass arm attached at the center of the celluloid protractor, A. The celluloid protractor is superimposed on the cross-section paper base, so that its index point, or center, A, is at a distance from the index point, B, of the protractor drawn on the cross-section paper, corresponding to the distances between the two observing stations, or the length of the base line.

The data are plotted in the following manner: The celluloid protractor is held securely with its zero on the south. The brass arm is set at the first minute's azimuth reading indicated by the theodolite at A station. A pencil mark is made on the celluloid protractor at the point where the azimuth reading indicated by the theodolite at B station intersects the brass arm, as determined by the lines of the protractor on the base paper. Each successive minute is plotted in the same manner and the points are numbered 1, 2, 3, etc.

As an example, let us take the data as to elevation angle and azimuths given in Table 1, and find the other data indicated in the table.

TABLE 1.

Station A.—Zero=north.							Station B.—Zero=north.	
Minutes.	Elevation angle.	Azimuth angle.	Distance from A.	Altitude.	Wind direction in degrees.	Wind velocity in meters per second.	Minutes.	Azimuth angle.
1	20.0	310.0	550	200	315	10.5	1	190.0 [315°=S. E.
2	18.1	315.0	1,255	410	324	10.7	2	205.0 324°=S. E.
3	18.5	320.0	1,820	610	336	10.2	3	220.0 336°=S. S. E.]
4	18.5	325.0	2,425	810	......	......	4	240.0.

[11] Now in preparation for a later issue of the REVIEW.—ED.

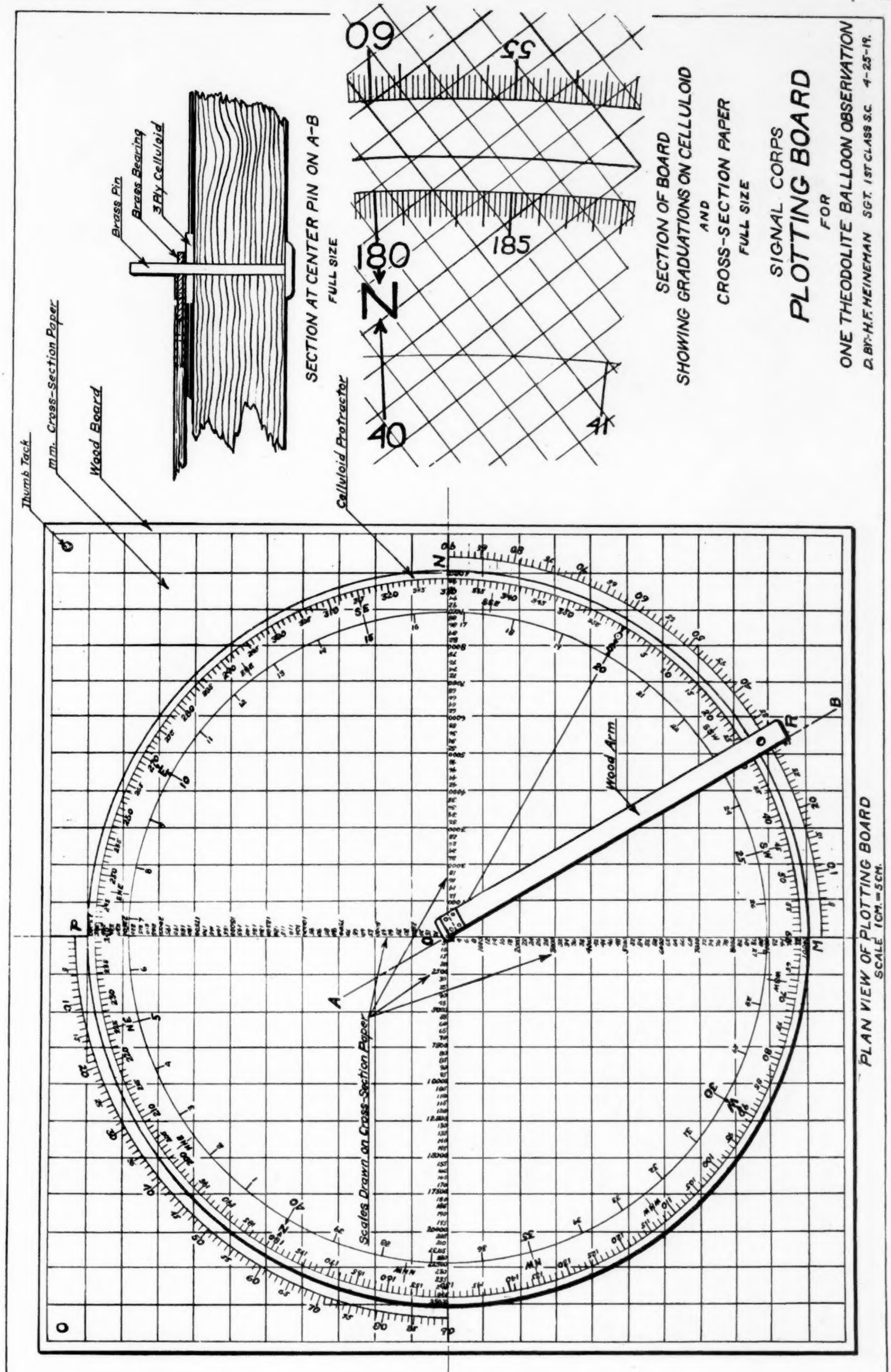


FIG. 4.—Essentials of the Signal Corps single-theodolite plotting board.

[To face p. 223.]

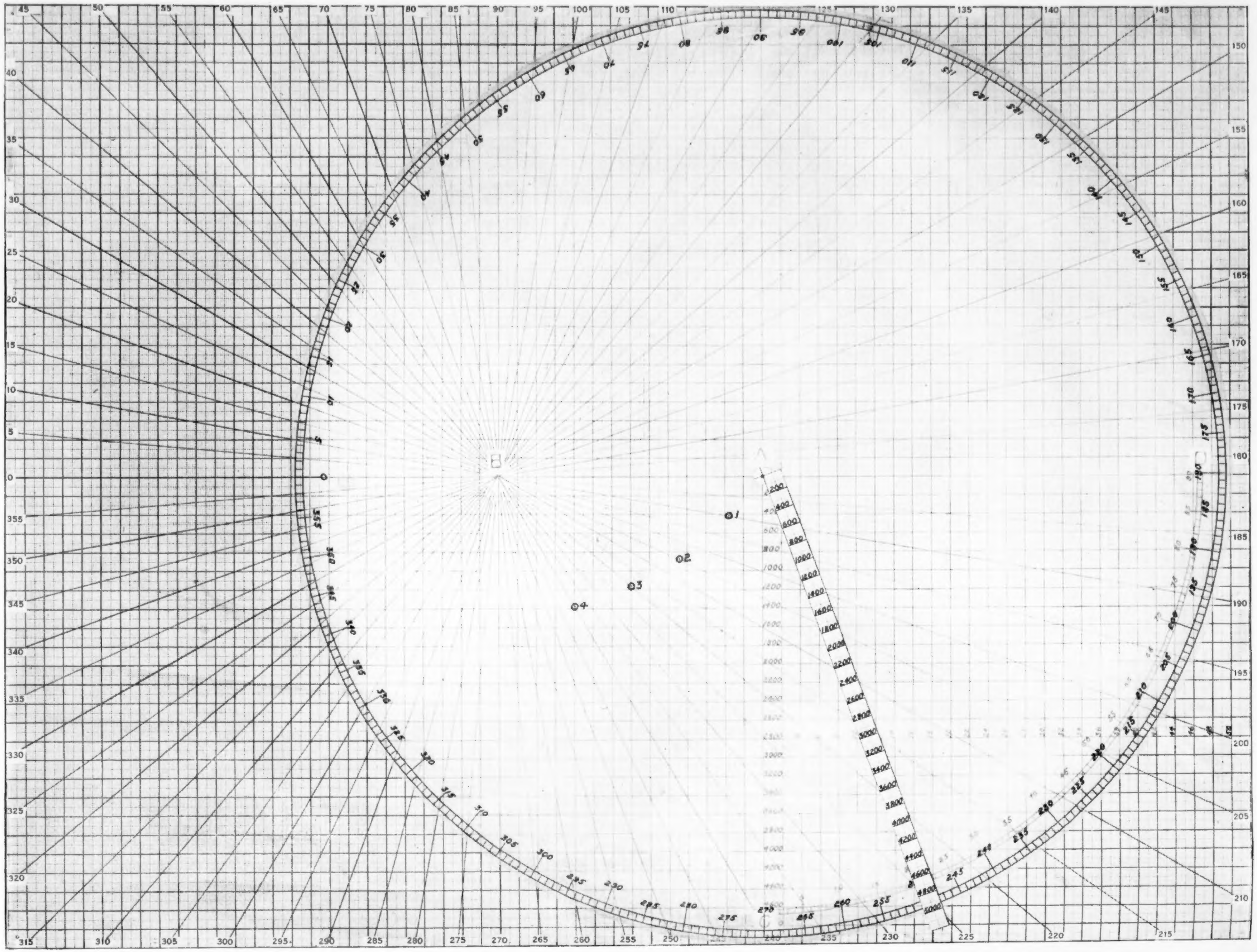


FIG. 1.—Two-theodolite plotting board.

The distance between stations A and B is 2,800 m., which on the plotting board is as indicated on figure 1 (the scale on the original being 1 cm. to 200 m.). The method of finding horizontal distances, altitude, wind directions, and velocities is as follows:

Set the celluloid protractor with 0° on station B. Set movable arm at 310°. From B follow line on azimuth 190°. Where the 190° line meets the protractor arm, place point 1. The distance of point 1 from A is shown by the scale on the arm to be 550 m. Set movable arm at 20° on the vertical quadrant CD (as now placed). Follow horizontal line from 550 on scale AC to arm. The altitude, which is measured by the distance on this horizontal line, is shown by the scale to be 200 m. The same method of finding horizontal distances and altitudes applies to all other minutes. To find wind direction at the end of the first minute move the celluloid protractor so that A and point 2 are on the same vertical line, and read wind direction at C from the celluloid protractor. For the end of the second minute set points 1 and 3 on the same vertical line, and read direction at C. To find the velocity at the end of the first minute measure from A to point 2. The distance A to 2 is 63 mm. on the full-sized plotting board; 63 mm. is equivalent to 1,260 m., the distance traveled in 120 sec., or at a rate of 10.5 m./s. The same result would have been obtained by dividing 63 by 6. For the velocity at the end of the second minute measure from 1 to 3, and divide by 6. The same method applies to all minutes following. Obviously, if the direction is changing from minute to minute, the velocities so computed will be somewhat too small. In practice, however, the results are sufficiently accurate, considering other sources of error.

SOME OBSERVED IRREGULAR VERTICAL MOVEMENTS OF PILOT BALLOONS.

By Lieut. I. R. TANNEHILL, Signal Corps, Meteorological Service.

[Dated: Fort Hancock, N. J., May 30, 1919.]

In a quiet atmosphere the rate of ascent of a pilot balloon does not differ materially from that computed from formula. For ordinary purposes it is a constant rate.[1] When there is active convection, however, there may be irregularities in the rate of ascent and the average vertical movement of the balloon may differ widely from that assumed. These variations from the computed rate are due, undoubtedly, to vertical movements of the air and may be taken as a measure of upward and downward components of wind movements.†

When there are ascending air columns, there must be rotary movements in many cases,* but these whirls do not appear in the horizontal projection of the balloon's path, for this path shows only the movement of the balloon with reference to a point on the earth's surface and the rotary motion would be such with reference only to the air in the stratum in which the balloon drifts. If there were a whirl under a cloud, the balloon would move in a spiral with reference to the cloud but not with reference to a point on the earth's surface, unless the cloud be stationary. A flight giving a wavy projection was replotted with reference to the air, by subtracting the average wind movement (in both magnitude and direction) from each balloon minute's movement. The result was a circular path, as expected. It seems that when the balloon is rising at rates greater than that computed such unusual motion is evidenced by a wavy projection.

The whirls which appear in the horizontal projections of the paths of pilot balloons seem to be whirls in another sense.[2] In these cases there seems to be a straight wind at any level, yet the balloon moves in a spiral course because it rises through strata with various wind movements. It does not seem likely from a study of such cases that the balloon would move in a whirl if it did not rise.

For these reasons—(1) that the balloon rises in a quiet atmosphere at a rate which is nearly constant and (2) that although convectional movements of the air may be typically rotary, the balloon does not necessarily (and probably rarely does) move in a spiral with reference to a point on the earth's surface—it seems safe to use the irregularities in the rate of ascent of pilot balloons as an indication of vertical air movements.

It is the object of this paper, then, to discuss briefly the irregularities that are observed in the ascensional rate of pilot balloons, particularly beneath clouds, as indicating vertical movements of the air.

As to unusual differences, the following is an illustration: On June 13, 1918, at 1:20 p. m., at Fort Monroe, Va., a pilot balloon with an ascensional rate of 193 meters per minute from formula[3] was observed with two theodolites to rise at an average rate of 396 meters per minute for five minutes before passing into a cumulus cloud. This occurred with a fresh northwest wind, temperature 23° C., and pressure 756 mm. In Table 1, the rate of ascent of this balloon is compared with others launched on June 12 and 13, 1918, at Fort Monroe.

TABLE 1.—*Heights of pilot balloons observed with two theodolites at Fort Monroe, Va., June 12 and 13, 1918.*

Date.	Time.	1	2	3	4	5	6	7	8	9	a	b
June 12, 1918	1:05 p. m.	200	440	700	920	1,195	1,430	1,680	.....	.....	187	240
June 13, 1918	8:25 a. m.	150	400	760	930	1,170	1,270	1,510	.....	.....	172	216
June 13, 1918	9:38 a. m.	....	520	800	1,030	1,220	1,520	1,750	1,960	2,150	196	239
June 13, 1918	1:20 p. m.	420	850	1,250	1,670	1,980	.....	.....	.....	.....	193	396
June 13, 1918	2:30 p. m.	270	350	520	600	725	855	1,105	1,375	1,650	....	....

In columns headed 1, 2, 3, etc., is shown the height of the balloon at the end of each minute. Column headed "a" gives the computed rate from formula and column headed "b" gives the actual average rate taken from the height of the balloon at time of last reading with both theodolites. Heights are in meters and rates of ascent in meters per minute.

It is apparent from an inspection of this table that there were local strong vertical movements during the afternoon of the 12th and the day of the 13th. Therefore, this phenomenal rate of ascent of one pilot balloon (396 meters per minute) was evidently due to atmospheric conditions. At 2:30 p. m., the same day, one hour and ten minutes later, a balloon was launched which rose very irregularly, as shown in the table. During the second and

[1] See pp. 211–212, above.

*Dust whirls at times become cloud-capped; also the whole base of a large cumulus has been seen to rotate slowly.—C. F. B.

†This explanation may not be applicable to those irregularities observed when local vertical currents may not be present. Thus, R. Wenger (Ann. d. Hydr. u. Mar. Met., 1917, vol. 45, pp. 121–137), after considering the air resistance of spheres in air of varying degrees of turbulence and the observed variations in the rates of balloon ascents, concludes that "The changes in the conditions of turbulence of the atmosphere explain qualitatively and quantitatively all variations which are observed in the ascensional rates of balloons," and that "It is not possible, from the variations of ascentional rate to come to any conclusions as to the vertical movements in the atmosphere."—C. F. B.

[2] See MONTHLY WEATHER REVIEW, Dec., 1918, 46: p. 553.

[3] See pp. 211 and 218, above.

fourth minutes this balloon rose only 80 meters, while during the ninth minute it rose 275 meters.

Cases in which balloons have moved upward much faster than expected are common, but an attempt by the writer to classify a number of these according to the kind of cloud in which the balloon disappeared did not give consistent results. It is, therefore, advisable to cite a few cases and show what may happen under such circumstances.

Since it appeared likely that topography affects the ascensional rate of a balloon during the first few minutes of flight experiments were made to determine the extent of this influence.

On May 12, 1919, at Fort Monroe, Va., two pilot balloons were filled, partly with air, partly with gas, so that the free lift was exactly zero and the balloons when released, with care, remained stationary. They were tested in a room the temperature of which was practically that outside. There was at the time a layer of strato-cumulus covering the entire sky. The temperature was 14.5° C., the pressure 759.9 mm., and the wind north, 4. 4 m./s.

The first of these balloons was released from the rampart at 1:50 p. m., and during practically the entire time of flight it drifted over the bay. It was assumed that the balloon's horizontal motion was that of the air, 4.4 m./s. From the distances by this assumption the altitudes were computed from elevation angle readings with one theodolite. This balloon rose irregularly to a height of 127 meters (from this assumption) on the 13th minute. It then descended slowly to 120 meters at the end of 16 minutes.

Balloon No. 2, released immediately afterwards, with a wind of 4.2 meters per second, rose (on a similar assumption) to a height of 694 meters on the 18th minute and then descended to 583 meters when lost at the end of the 21st minute.

This north wind, coming from the water, was probably thrown upward in passing over the ramparts. Since the sky was clouded it is apparent that there was no appreciable heating effect on the balloon. These figures seem to indicate that local currents at the surface may affect the rate of ascent of a balloon during the first few minutes. Certainly, after that time, the influence of clouds in some cases may be marked. The errors which might arise in an assumption of a uniform ascensional rate from formula are obvious.

It has been shown that the actual rate of ascent may in some cases depart materially from that calculated from formula. What effect does such a departure have upon the wind aloft data secured from one-theodolite observations, assuming altitudes from formula? An individual case may be interesting.

At Park Place, Houston, Tex., January 6, 1919, the projection made from a balloon observation at 2:58 p. m., 90th meridian time, was as shown in figure 1. The ascensional rate of this balloon from formula was 182 meters per minute. There were at the time ten tenths of alto-cumulus clouds. Observations before the ascension showed the clouds to be moving from southwest by south, but from the flight it was found that the balloon was moving from the west on the 8th minute, or just before it passed into the clouds. One theodolite was used. The clouds were assumed from this observation to be 1,600 meters high.

Later, observations showed that the clouds were still moving from the same direction, southwest by south. It therefore seemed that the projection was in error. The fact that alto-cumulus clouds should be much higher seemed to indicate that the assumed altitudes were wrong. Referring to figure 1, let us assume that the balloon moved from the 7th to the 9th minutes in the direction in which the clouds moved. The locations of the balloon would have been at 8a and 9a instead of at 8 and 9. This would necessitate an ascensional rate of the balloon during the 8th minute of 400 meters per minute and during the 9th minute of 600 meters per minute. The balloon, being lost during the next minute, the actual altitude of the clouds may have been over 3,000 meters.

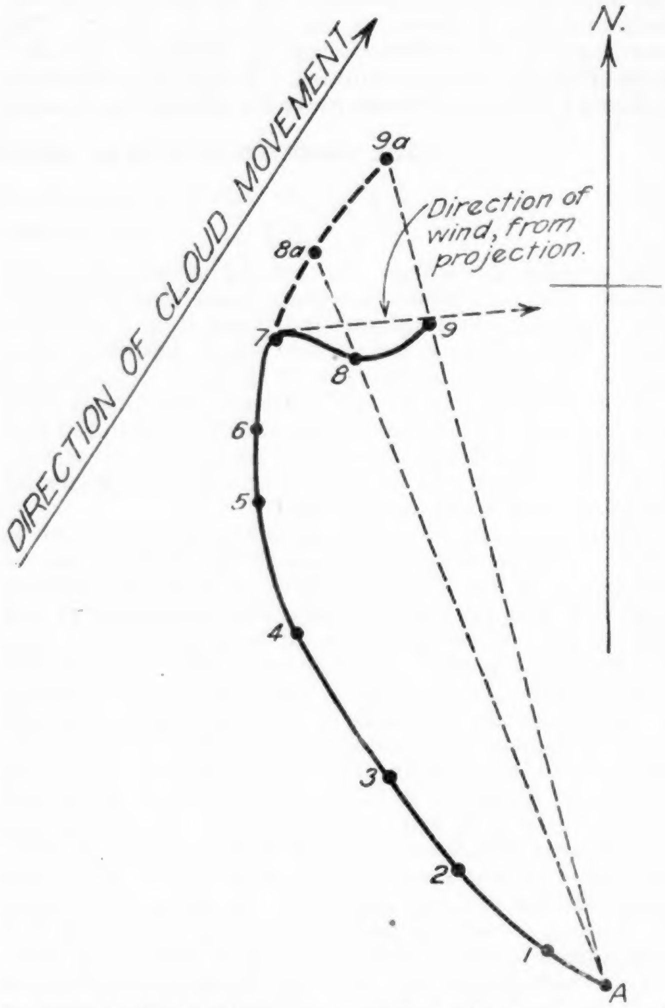


FIG. 1.--The solid line A to 9 is the path of the balloon projected upon the horizontal plane, and is from readings with one theodolite. The figures 1, 2, 3, etc., show the position of the balloon at the end of each minute. The figures 8a and 9a show probable positions of balloon at the end of the 8th and 9th minutes, from movement of clouds into which the balloon passed. From these distances, A-8a and A-9a, the corrected altitudes were computed, using the angle of elevation.

That there was such an updraft under these clouds is possible. It began to rain at 9:40 p. m.

The peculiar shape of this projection was not due to errors in observation. As a check, another balloon was launched at 3:28 p. m. and the same abrupt change in direction, using one theodolite, was shown. Errors in the assumed height, therefore, produce errors not only in distances traveled and consequently in wind speeds but produce serious errors in direction of the wind as obtained with one theodolite, provided the balloon is not moving straight away from the station.

* * * * *

In a paper by A. E. M. Geddes, published in the Quarterly Journal of the Royal Meteorological Society, April, 1915, volume 41, pp. 123–135, pilot-balloon observations at the Observatory, King's College, Aberdeen, are discussed particularly with reference to wind values aloft in relation to the gradient wind. The rates of ascent of the balloons are given, however, and tabulated according to the kind of cloud in which the balloon was lost.

In the case of strato-cumulus clouds, it is stated that for corresponding lifting powers the upward velocities were greater than on clear days. (Cf. footnote † on p. 223.) No sudden increase, however, was observed on passing into the cloud.

A sudden increase in upward velocity was observed in all cases but one where the balloon passed into cumulus clouds. In one of these flights, the balloon rose at a rate of 6.2 meters per second immediately before passing into the cumulus cloud. This gives a rate of 372 meters per minute, which is not much different from the high rate noted at Fort Monroe on June 13, 1918.

With fracto-cumulus clouds there was a sudden rise at the base of the cloud. This sudden increase was not so large as in the case of cumulus clouds.

With stratus clouds there was a fairly uniform vertical velocity with no remarkable increase on entering the cloud.

In conclusion, it is stated that "in making observations with one theodolite it consequently becomes incumbent on the observer to take note not only of the free lift of his balloon, but also to study the type of cloud into which his balloon is likely to disappear, and the tendency of the barometer, before assigning any definite vertical velocity. Even then the assumption of a uniform vertical velocity is apt to round off corners and bring the condition of the atmosphere into a more ideal state than it really is. When a considerable altitude is reached, say over 3 kilometers, surface influences will have disappeared, and the one-theodolite method may be superior to the other, seeing that the base is often small compared with the distance the balloon has traveled."

* * * * *

In many instances there is not any sudden increase in rate of ascent when the balloon passes into cumulus clouds. This does not prove, however, that such vertical movements do not exist. With two theodolites the balloon is often lost at one station two or even five minutes before it is lost in or behind the cloud at the other station. The number of cases in which the balloon actually disappears in the cloud at both stations at the same time is comparatively small. Consequently it may be that in many instances the balloon passes behind the cloud or between two clouds.

In conclusion, it may be said that inasmuch as it is often necessary to observe a balloon with only one theodolite or to continue an observation when the balloon is lost to one observer, it is necessary to make a careful inspection of clouds before concluding that the drift of the balloon as plotted represents the movement of the wind. A considerable departure of the actual from the computed rate will, with one-theodolite observations, produce a serious error in the wind data deduced.

THE WORK OF THE AEROGRAPHIC SECTION OF THE NAVY.[1]

By Lieut. Commander ALEXANDER MCADIE, U. S. N. R. F., Senior Aerographic Officer.

[Dated: Harvard University, Blue Hill Observatory, Readville, Mass., Mar. 27, 1919.]

Early in January, 1918, the Assistant Secretary of the Navy asked Prof. McAdie to supervise the organization of an aerographic section in the Navy. Enrolling as lieutenant commander in the Reserve Force, this officer reported to Capt. N. E. Irwin, United States Navy, Director Naval Aviation Operations. He sailed for Europe early in April, accompanied by eight aerographic officers to take over certain observations in the British Isles and France.

Instruction in meteorology had been given in a general way at a number of naval air stations, but definite work in aerography,[2] similar to that carried on at British, French, and Italian air schools, may be said to have had its beginning on December 3, 1917, when the first group of students who had finished the course in the Ground School at the Institute of Technology, reported at Blue Hill Observatory for an intensive course of instruction in aerography. To aid in the rapid establishment of the service, Lieut. W. F. Reed, jr., also gave considerable practical and theoretical instruction at Pelham Bay, N. Y., during January, February, and March, 1918. A knowledge of the structure of the atmosphere, the relation of wind and pressure, the variation of wind with height, eddy motion, turbulence in relation to gustiness, the use of sounding and pilot balloons, forecasting for aviators at foreign and home stations, and some familiarity with the work of modern investigators—Dines, Shaw, Rotch, Gold, Cave, Taylor, and others—were regarded as necessary. As the instrumental equipment of the observatory includes many European instruments not found elsewhere in this country, students had opportunity to familiarize themselves with such instruments. The work was upon a postgraduate basis and the men entering were required to hold university degrees or possess a training equivalent to that required for a degree at the Massachusetts Institute of Technology. In all 56 men took the course. These (with the exception of four) received their commissions as ensigns. Twenty-eight American universities or colleges were represented. Of the whole number 22 had foreign service.

Through the courtesy of the British Admiralty, officers upon their arrival in Europe were permitted to spend two weeks at selected air stations, and thus get in touch with latest developments.

The British Admiralty also kindly agreed to furnish 20 complete outfits for aerographic observatories (see Fig. 2, opposite p. 227, below).

Many of the officers were elected Fellows of the Royal Meteorological Society and while in London were made welcome at the library and offices of the society. We were also made to feel at home in the Meteorological Office and were allowed the privilege of being in the Forecast Room when work was in progress. It must be remembered that at this time all weather information was confidential. Harmonious relations were maintained with the Air Service of the Army in France. Lieut. Commander McAdie and Maj. Bowie had many conferences at the Bureau Central Météorologique, and received every courtesy from the director, Prof. A. Angot.

By this cooperation, the Navy aerographers on the coasts of Ireland, England, and France became part of

[1] Published by permission of the Secretary of the Navy.

[2] "Aerography" as here used is practically synonymous with "meteorology," except that it implies that the main emphasis of the work had to do with free-air conditions.—EDITOR.

the receiving and distributing network of weather-reporting stations. Reports from sea, however, were scant, owing to the ban upon the use of radio.

At each observatory, when in full working order, there were two aerographic officers and six quartermasters, class A, aerographic. Commanding officers could thus call for information and advice at any hour of the day or night. Sondages at some important coast stations were taken every two hours. Many commendatory reports have been made regarding the service in connection with the operation of both lighter-than-air and heavier-than-air machines. Particularly in connection with the successful operation of blimps was the value of wind directions and velocities at different levels apparent. At some stations the number of hours of patrol increased decidedly after the establishment of the aerographic observatory. In addition to surface and flying level winds, the aerographer was expected to forecast visibility and especially advection fogs and sea fogs. Thunderstorms, gustiness, changes in the lapse rate (vertical gradient) of temperature as well as horizontal gradients, heavy rains, likelihood of snow at high levels, frosts, and surface temperature inversions were regarded as subjects bearing directly upon the safety of fliers and therefore to be noted and investigated with all diligence.

At first, American naval aerographers followed rather closely the methods of the British observers in the Hydrographic Department of the Admiralty, but in France they soon discarded the old English units and also modified materially the methods of work. Many good suggestions came from various members both in the field and at home. The two-theodolite method originally used at Blue Hill was soon displaced by the one-theodolite method of following pilot balloons, and while it is fully recognized that this method is open to criticism, it is quick and worked fairly well in actual operation. Several rapid methods of calculation were designed by the officers at Blue Hill. All of these can not be described here, but those of Ensigns Davy, Twitchell, and Mall were successfully tried out. Inasmuch as a short review of some of these methods may be of interest to others working in this field, I append a note by Ensign Mall, which, while not describing his own automatic device, gives briefly the cardinal points of the Davy Rapid Calculator and the Twitchell Vector. An extended paper on the subject has been prepared by Ensign Twitchell, but can not be given here. Ensigns Townshend, Parsons, and Davy designed an automatic balance for use in filling balloons, giving free lift and dead weight. Ensign RuKeyser designed a cage for approximately determining free lift, for use where other methods could not apply.

Some studies of the depth of the sea breeze in the East Gulf were made by Lieut. Reed at the Pensacola station.

During the absence of Prof. McAdie abroad, the following lectured to the classes: Chief Observer L. A. Wells, Ensigns Keyser, Buck, Townshend, Davy, Parsons, Mall, and RuKeyser. Lieut. R. F. Barratt was in charge of foreign stations after the return of the senior aerographic officer to the United States.

Eighteen stations were established in France, six in Ireland, and two in Italy. An account of the equipping and instrumental work in the United States is given in the following note by Commander Jewell.

WORK OF THE NAVAL OBSERVATORY IN CONNECTION WITH NAVAL AEROGRAPHY.

By Commander C. T. Jewell, U. S. N., Retired.

[Communicated by the Superintendent, Naval Observatory, Washington, Mar. 14, 1919.]

The Naval Observatory's proper function in the development of aerography was the procurement and issue of suitable instruments. This was accomplished under the superintendency of Rear Admiral T. B. Howard, U. S. N., retired.

When the policy of establishing naval flying stations at home and abroad was definitely adopted in the summer of 1917, the Observatory, on its own iniative, added to the allowance list an aneroid barometer, a wet-and-dry-bulb psychrometer, and a masthead anemometer, all Navy standard articles of which there was a stock on hand, so that the Air Stations could keep a record of weather conditions commensurate with that kept on board vessels of the Navy.

The following winter it developed that there was need of more extensive equipment. An appeal to the Observatory was made in December, 1917, for pilot balloons and theodolites for air sounding, and in the following summer the Observatory went into the market for a full set of meteorological instruments for air stations in the United States.

A step in advance in the way of cooperation with foreign observers was made at this time by having the charts on which records were kept by recording instruments of various types printed in metric and centigrade scales rather than the usual English units.

Wind vanes were supplied without registers, for visual observation only, as it was early recognized that our business dealt with the upper air currents and not with the surface winds.

An anemometer recording the passage of air equal to a wind movement of 1/60 of a mile had been adopted for naval use before the war. These were issued to Air Stations at home. Air Stations abroad were supplied with instruments obtained abroad without any action on the part of the Observatory.

After supplying instruments recording in metric units, the pressure, temperature, and humidity at the stations on shore, the Observatory turned its attention to wind-measuring instruments. The Draper Instrument Co., of New York, supplied 20 anemoscopes of their design. These instruments show the exact direction of the wind at any moment, giving a record which illustrates the variability of the wind as well as its general direction. For wind pressure and velocity, the department finally adopted a modification of Dine's anemobiagraph.

The development of the Aerographic Service at the home stations is practically the work of Ensign E. B. Buck, U. S. N. R. F. First he had charge of the aerographic students at the Blue Hill Observatory; later as an assistant to the Director of Naval Aviation, he advised as to the detail and station of the aerographic officers he had trained, and finally, as an assistant to the superintendent of the Naval Observatory, he handled the minutiæ of getting the home stations equipped and operations started. Key West, Miami, Chatham, Halifax, and San Diego were actually at work keeping records and making forecasts at the time the armistice

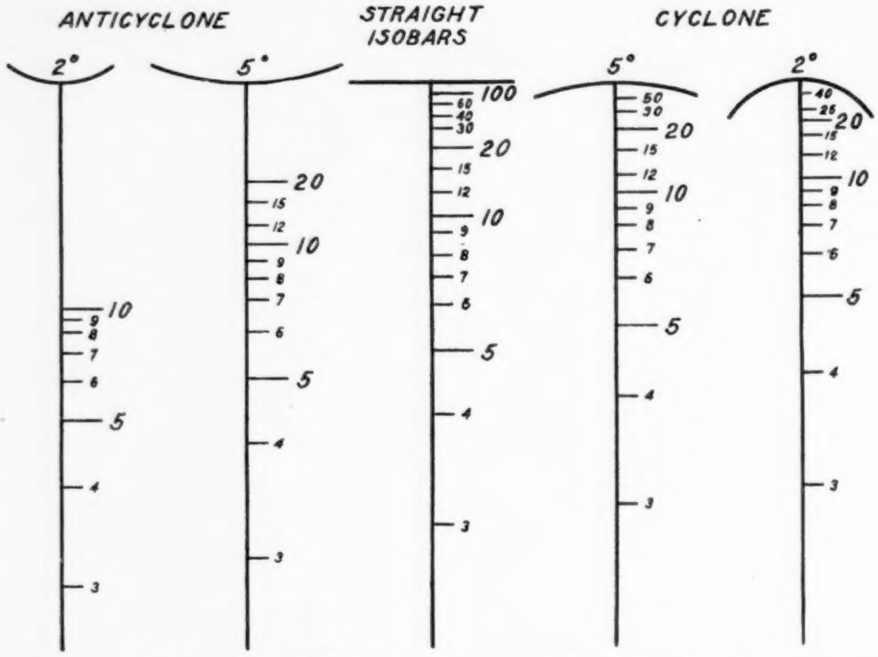


FIG. 1.—Gradient velocity scales, for use on British daily weather report charts (scale 1/20,000,000). Velocities in meters per second.

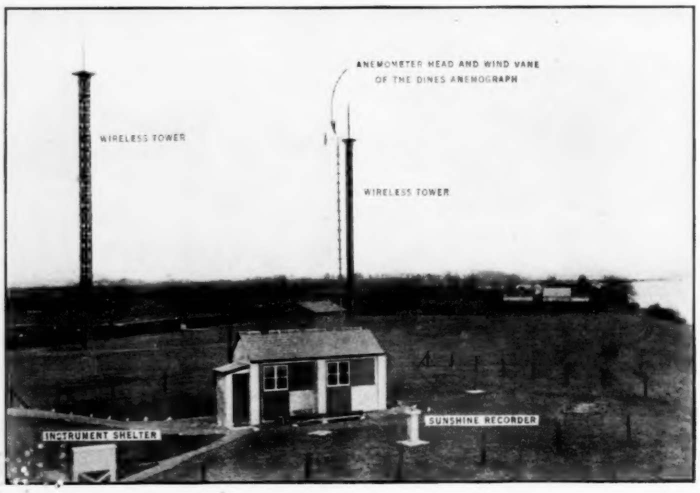


FIG. 2.—Meteorological hut, U. S. Naval Air Station at Wexford, Ireland.

was signed. Bay Shore had been equipped, but never operated. Halifax and Chatham were supplied at this time with equipment for pilot-balloon work, and five complete outfits for France were on the wharf awaiting transportation.

In addition to the Air Stations above named, Brunswick, Ga., and Hampton Roads, Va., have since been put on an operating basis. Rockaway Beach, Long Island, N. Y., has also been equipped. Several of our stations are now regularly cooperating with the Weather Bureau, sending in daily reports of conditions in the upper air and receiving regular forecasts. At nearly all the patrol and flying stations, commanding and flight officers are kept informed constantly of the force and direction of the wind at flying levels and of the weather to be expected during practice hours.[1]

For more than a year the Observatory has been working to secure a suitable recording instrument for measuring meteorological conditions in the upper air while carried by a seaplane in flight. Two forms of instruments for this purpose are now nearing completion. Their perfection will complete the instrumental outfit for Naval Aerography.

[1] See map p. 209 for location of the naval aerological stations.

METEOROLOGY IN THE NAVAL AVIATION SERVICE OVERSEAS.

RUY H. FINCH, U. S. N. R. F.

[Dated: Weather Bureau, Washington, Feb. 14, 1919.]

Aside from bombing a few ports held by the Central Powers and some convoying of ships, the work of naval aviation was primarily hunting submarines. Hence forecasts and data were mainly for use over the ocean.

Forecasting for the coastal waters of northwestern Europe presented many difficulties, especially to those who had been accustomed to having a broad expanse of land to the west from which reports are received showing the more or less regular progress of HIGHS and LOWS. There, too, one had to deal with a series of LOWS with only occasionally an intervening traveling HIGH. The HIGHS that most commonly affect the western coast of Europe—oceanic conditions—are the slowly shifting, sometimes stationary ones either of continental origin or from the Azores region. The first intimation of the approach of a storm to northwestern Europe in the absence of wireless reports from the Atlantic is from the effects due to the storm itself—the formation of cirrus and other characteristic clouds, the falling of the barometer, and the backing of the wind at the westernmost stations. This latter often seems to anticipate a fall of the barometer, but it is still a mooted question whether the backing of the wind precedes or accompanies the change from stationary, or rising, to falling barometer.

At many of the American stations it was impossible to get the British forecast, or any reports, in time to help in making the morning forecast; and one had to be guided by local conditions and by old reports. The backing of the wind and fall of the barometer would herald the approach of a storm; but, of course, only a short time before the onset. Clouds, however, gave more advance information of the coming LOW. Along the western coast of France and over the British Isles the wind circulation nearly approaches the ideal circulation found in well-defined storms over the ocean. Most of the meteorological huts were stationed along or near the coast, usually near the landing places of the seaplanes, and were excellently situated for cloud observations. By noting the appearance and direction of clouds of the cirrus level, and the time interval before the developing of alto-types, one could get a good idea of the intensity and distance away of coming storms. By noting departures from expected wind direction and cloud movements, and assigning a reason for such departures, one could often locate secondary depressions, even when they were passing to the south of the observer. When low clouds prevented good cloud observations one had to be guided by the wind direction and the barometer. In many cases elaborate cloud observations were unnecessary, for short-range forecasts—6, 12, and 24 hours—were all that were desired.

Synoptic charts were drawn, and, though usually too late to be used in making morning forecasts, they gave a good check on the interpretation from local conditions, and aided one in studying the causes and effects of weather happenings. In cases where synoptic charts were available in making forecasts they were used only in conjunction with local conditions. Land-and-sea-breeze conditions occasionally afforded easy forecasting of wind velocity and direction.[1]

Forecasts included wind velocity and direction from the surface up to 2,000 or 3,000 feet, weather (rain or fair), height of clouds if low, and visibility. At stations where dirigibles were used forecasts had to be more definite and a closer watch kept of the weather than at seaplane stations.

Visibility is of prime importance in hunting submarines from aeroplanes. A haze that would permit of fair discernment of large objects would completely obscure a periscope or a submarine slightly submerged. The forecast of visibility was for the distance in miles at which selected objects could be clearly seen. Colored glasses for observing through haze were used with some success. By noting the causes of poor visibility, and by correlating visibility at sea with the visibility and general conditions near the meterological hut, one could make good forecasts of the visibility seaward. Although a qualified observer, it was mainly for visibility correlations that the writer went up on a patrol as observer.

The British forecasts always included the gradient velocity, which was assumed to obtain at 1,500 feet. The British Admiralty, however, were inclined to take 2,000 feet as the average level at which the gradient velocity is reached. The current gradient velocity was obtained from the weather map by means of transparent scales similar to those drawn in figure 1. They were calculated for the latitude of the British Isles for use on the daily weather reports (scale 1/20,000,000) with isobars drawn for every 5 millibars. Several radii of curvature for both cyclones and anticyclones are usually given, and one or two trials will usually show the curve nearest the required isobar. Then, by noticing where the next isobar crosses the scale, the wind velocity is read off. From theoretical considerations of the decrease of density and the pressure gradient with increase of elevation tables have been computed giving velocities for all elevations up to 30,000 feet corresponding to gradient velocities at the surface. They were but little used and are of doubtful accuracy.

[1] See discussion of forecasting in western Norway: MONTHLY WEATHER REVIEW Feb., 1919, 47: 90-95

Wind velocity and direction aloft were obtained by means of pilot balloons, and all stations were supplied with equipment for making pilot-balloon ascents. The ballons were inflated to give a rise of 400 or 500 feet per minute, according to the size of balloon used. This rate of rise facilitated rapid calculation; and by the single-theodolite method, with the theodolite near the office, two men could take the data, make the horizontal projection of the balloon path, and within one minute from the time the balloon was lost, complete the tabulation of the wind velocity and direction for all levels reached. A check on the rate of rise was sometimes made by the two-theodolite method. It showed that a balloon with the 500-foot rate varies from 425 to 600 feet per minute, though usually it is not very far from 500 feet. Such a departure from the assumed rate would cause a large percentage of error, but for velocities most suitable for flying it would mean an error of only a few miles an hour. In making night ascents a small candle lantern was tied to the balloon.[1]

Data from the pilot-balloon ascents as well as from surface instruments were used in plotting dead-reckoning courses for seaplane patrol. The wind direction was given in degrees to facilitate computing the drift angle, as most patrols consisted of many courses. Surface-wind data were obtained from the Dines anemograph, which gives instantaneous wind direction and velocity. In case the outlook was unfavorable for a dawn patrol upon the advice of the station meteorological officer the planes were not taken out of the hangars; and if dangerous winds were expected when planes were out it was the duty of the meteorological officer to see that they were recalled.

The type of meteorological hut used in British and American air stations is shown in the accompanying photograph (fig. 2).

[1] See pp. 221, above.

BLUE HILL METHODS OF "PILOT BALLOONING."[1]

By IVOR MALL, Ensign, U. S. N. R. F.

[Dated: Blue Hill Observatory, Readville, Mass., March, 1919.]

Pilot balloons are used to determine wind velocity and direction at various altitudes. To accomplish this, the balloon is released and its successive positions at intervals of one minute are observed through a theodolite. The vertical, or altitude, angle, and the azimuth, or horizontal, angle are noted at each of these minute intervals. From these data, and an assumed constant rate of ascent, the velocities and directions at different levels are calculated.

The solution of the data makes use of simple geometric and trigonometric principles. In order to make the operation more vivid, it is well to concentrate the attention

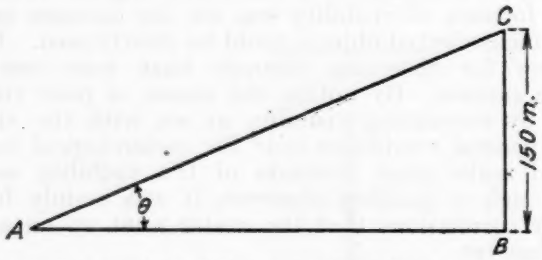


FIG. 1.—A represents the point at which we are standing and what we shall call the base; C is the position of the balloon; B is a point projected vertically below C; θ is the recorded vertical angle.

on the procedure and try to visualize what happens when the balloon is released, and then to determine the value of the recorded data.

Let us stand with our backs to the wind and with a properly inflated balloon at hand. We will assume that the balloon when released will have a constant rate of ascent (150 m./min.). We release the balloon and it starts to rise and is carried out and away from us by the force of the wind. At the end of one minute we observe its position with the theodolite. According to our assumption its height is 150 meters. We record the vertical angle. This is represented in figure 1. AB represents the horizontal distance with respect to the earth that the balloon has traveled in one minute. If we divide the distance AB by 60, we obtain the wind velocity in meters per second (m./s.).

[1] Published by permission of the Secretary of the Navy.

To find AB we have the following trigonometric relation:

$$BC \cot \theta = AB.$$

With AB determined we convert it into terms of velocity as explained above.

The above description shows what has happened in the vertical plane. If the wind direction were constant, this reasoning would be sufficient, but as this is not true another condition is introduced the explanation of which follows.

Let us go back to the point where we released the balloon. We observe its movement at minute intervals as it moves away. After a few minutes we notice that the balloon is being deflected to our right. This would

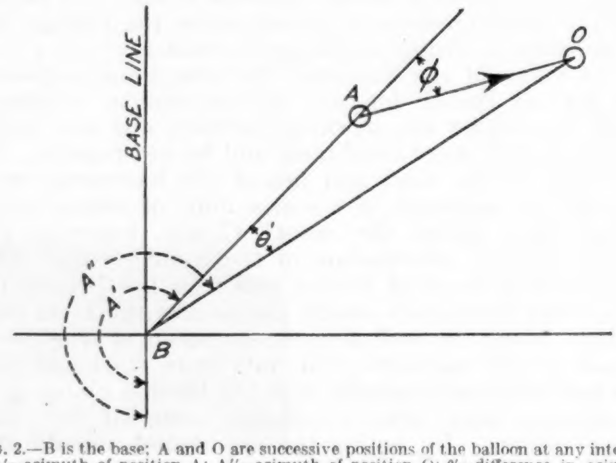


FIG. 2.—B is the base; A and O are successive positions of the balloon at any interval; A'=azimuth of position A; A''=azimuth of position O; θ'=difference in azimuth; ϕ=angle between line of sight of nearest position of balloon and the line of travel of the balloon.

lead us to the conclusion that the wind at the higher levels is from our left rear. In other words, the wind direction is changing as we go aloft. This variation is measured by noting the change of the horizontal angle, or azimuth. A movement takes place laterally with respect to the horizontal plane, which is represented in figure 2. The line AO represents the true balloon travel, hence its velocity. As the balloon has been blown from A to O, it

also shows the direction of the wind as indicated by the arrow. It is now necessary to obtain the direction of AO with respect to the "base line."

If the line of sight BA is extended it forms with AO the definite angle ϕ. It is obvious that if ϕ is added to A′ the true direction of AO with respect to the base line is obtained.

A complete observation will necessitate dealing with motion in both the vertical and horizontal planes. The "Davy Calculator" (fig. 3), combines polar and rectangular coordinates, and thus makes it possible to represent both planes on the same surface. A reference to the "Davy Calculator," figure 3, will show that an application of rectangular coordinates gives a graphical solution of the relation, BC $\cot\theta$ = AB. The polar

To apply to "Calculator" (fig. 3).

1. Read up on the left-hand scale (vertical distance in meters) to 150. Follow this over to where it intersects the altitude angle 31.8°. Project this intersection vertically downward to the bottom scale, and read horizontal distance and velocity directly. (Dist. = 220 m.; vel. = 4 m. p. s.) The direction from which the wind is coming is the same as the azimuth.

2. Read up on the left-hand scale to 300 meters. Follow this line over to where it intersects the vertical angle 35.6°. Project this intersection vertically downward to the bottom scale. Reference is now made to the accompanying figure 4.

X is the point just established on the bottom scale. With BX as a radius and B as a center, describe an arc

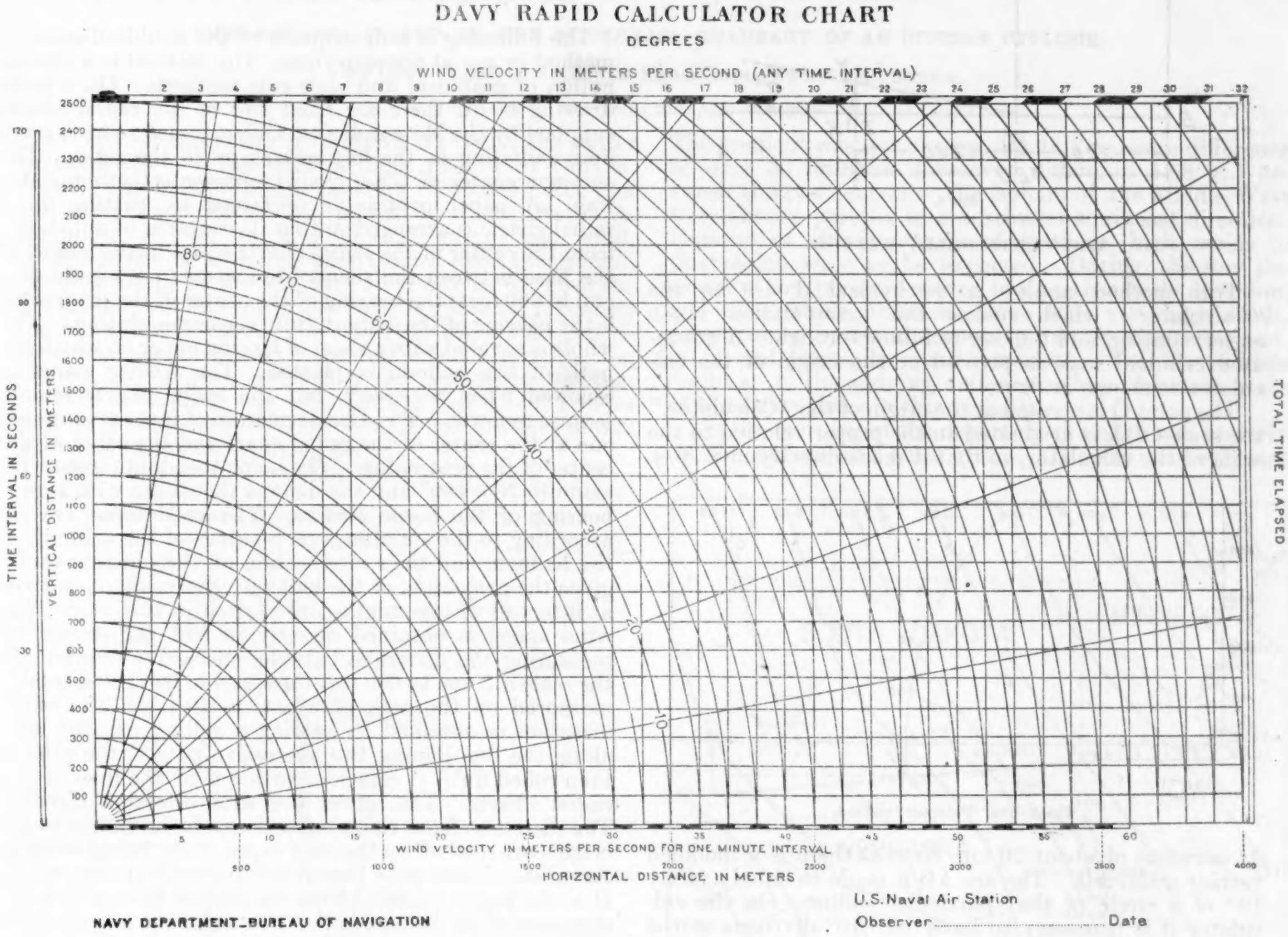


FIG. 3.

coordinates form a graphical solution of a change in azimuth. To show the use of the "Calculator," the calculation for the following data will be followed through.

Time.	Height.	Altitude.	Azimuth.	Velocity.	Direction.
	Meters.	°	°	*M./s.*	°
2:55					
2:56	150	31.8	90.5	4.0	90.5
2:57	300	35.6	93.2	3.0	97.5
2:58	450	34.6	95.2	3.7	100.7
2:59	600	33.1	101.0	4.5	115.2
3:00	750	31.4	107.0	4.5	124.0

of a circle equal to the difference in the azimuths 1 and 2 (2.7°) and establish the point Y. Project vertically downward from Y and establish the point Z on the bottom scale. The velocity for the second period of observation is equal to (BZ − BW) = WZ = 3.0.

If the angle YWZ (7.0°) be added to the azimuth of the previous observation, we obtain the direction of WY, or (90.5 + 7.0) = 97.5°.

Follow through identical steps for all observations.

The following points should be noted:

1. If the difference in azimuth if 5° or less it is not necessary to swing up through this angle to obtain the

velocity, as the second point when projected down will nearly coincide with the first; but it is necessary to swing this point up to obtain the change in direction of the wind.

2. The angle ϕ will not always be added to the previous azimuth. A set of four rules is furnished with the "Calculator" which are to be applied in determining the wind direction.

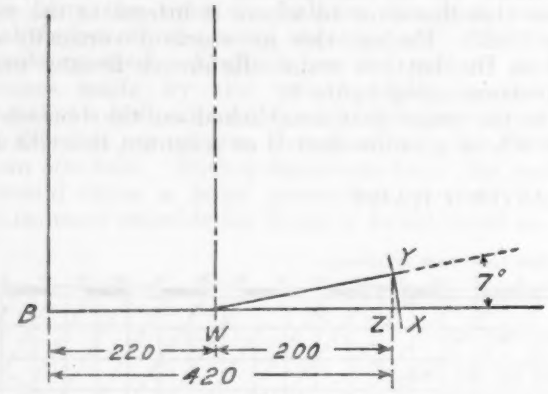


FIG. 4.

THE "TWITCHELL" METHOD.

This method applies a mechanical device to the "Calculator" which makes the manipulation much easier, simpler, and quicker to follow through. A graduated celluloid scale is pivoted at the origin of the calculator as shown in figure 3.

The point O is pivoted at the origin of the "Calculator." the scale OBX is graduated in the proper relation to the scale of the calculator, so that it reads directly in m. p. s.

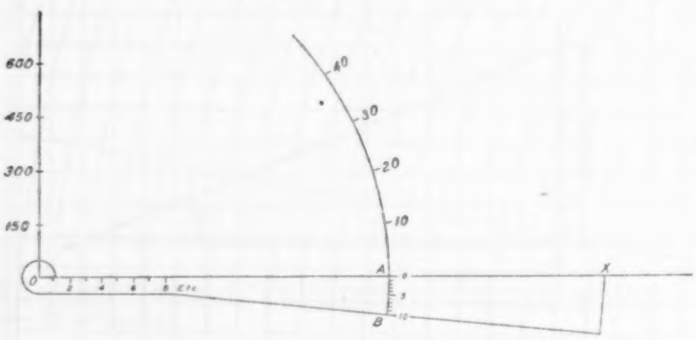


FIG. 5—The "Twitchell" method.

At a radius of about 20 cm. from O there is a modified vernier scale, AB. The arc AB is made to equal exactly 10° of a circle of that particular radius. On the calculator it is necessary to have only 10° divisions as the scale allows for any fraction between these divisions.

The use of the rule is as follows:

We will assume the same data as before.

1. Read up the left-hand distance scale to 150 meters. Set the lever so that the ruled edge lies on the 31.8° line. Read over on the 150 meter line until it intersects this edge. Follow this point vertically downward to the scale below. Move the lever down so that the ruled edge coincides with the bottom of the chart and read the velocity from the lever in m. p. s.

2. Read up the left-hand distance scale to 300 meters. Set the lever to read the vertical angle 35.6°. Find the intersection with the 300-meter line and project the point vertically downward to the bottom scale. By means of the lever establish the point Y as in figure 3. By means of an auxiliary scale measure the horizontal and vertical distances of this point from the point W, figure 3, and lay them off from the origin. They determine a point which in turn determines ϕ. Let the lever measure this angle (7.0°). Add this to the previous azimuth and obtain the wind direction $(90.5+7.0)=97.5°$. The distance WZ gives the wind velocity.

The steps are the same for succeeding operations.

The same rules for finding wind direction apply as with the "Calculator."

BRITISH PILOT-BALLOON METHODS: THE SHOEBURYNESS SYSTEM.

[Reprinted from Meteorological Office Circular 30, Nov. 26, 1918, pp. 1-2.]

The following is a description of the double-theodolite method in use at Shoeburyness: The method is a combination of graphical and slide-rule methods. On a large drawing board there are fixed two of the radial charts supplied by the Meteorological Office, joined so as to have lines radiating to the left as well as to the right. The common center of these charts represents the home station. A paper protractor (obtained by cutting up a radial chart) is arranged so that its center is at a distance from the center of the radial charts equal to the length of the base between the theodolite-stations on a scale of 2 cm. to 600 feet; the bearing of the center of the protractor is the bearing of the distant, from the home, station. The whole is covered with a sheet of tracing paper on which the path of the balloon is plotted. The tracing paper is renewed when necessary, but the radial charts seldom require renewal. Two Chesterman steel tapes are pivoted one at the center of the radial chart and the other at the center of the protractor. The home theodolite is set with azimuth N.=180° and the distant theodolite with zero—bearing of the home station. The steel tapes are set according to the simultaneous readings of the azimuth of the balloon, and their intersection on the plotting tables gives the projection of the balloon. Successive positions at intervals of one minute are plotted in this way. The wind speed is obtained directly in feet per second by measuring the distances between successive points. As the scale is 2 cm. to 600 feet the speed in feet per second is measured on the scale of 2 cm. to 10 f./s. The wind-direction is obtained by setting a rolling parallel ruler along the line joining two successive points; the ruler is then rolled until it coincides with one of the lines of the radial charts. This gives the wind-direction directly. The distances from the intersections on the charts to the origins are read off on the steel tapes, 2 cm. being taken as the unit. These give HcotE/600 for each station where H is the height in feet above the station from which the elevation of the balloon is E. From this the height above each station is computed by slide-rule. A pilot balloon slide-rule is used: 1 on the inner slide is set against 6 on the main slide. The tangent cursor is set to the complement of the angle of elevation and the inner slide is then set so that the horizontal distance of the balloon from either station, as measured on the plotting board, falls under the cursor. Height in feet is then read against the end of the sine-scale.

The ends of the base and the office where the computing is done are connected by telephone. The telephone installation is arranged so that any observer who is using the telephone can speak to and hear either of the other two. This is the case whichever base is being used. Five observers are required; they are allocated as follows:

Two at the station from which the balloon is being released (the home station).

One at the other station (the distant station).

Two in the office computing.

At the home station, one of the observers follows the balloon. The other, who is at the telephone, gives the needful time signals and transmits the observations of his own station to the office: the observer at the distant station transmits his own observations on hearing the time signals given by the home observer. To prevent any confusion, the routine adopted is for the distant observer to send his readings through first, and for the home station to send theirs immediately afterwards.

In the office there are two computers. The one who is wearing the telephone receives the observations and notes them on the special form, at the same time giving them verbally to the second computer, who plots them on his radial chart and reads off the values HcotE/600, wind speed and direction. He gives these to the first computer, who enters them on the form and, by means of the slide rule, calculates the height of the balloon above each station. The necessary computing is done before the reading for the next minute becomes due. Thus the whole work can be done during the balloon ascent, and results are obtained just as rapidly as with single-theodolite observations.

Telephone connections are available at each angle of a triangle, which is nearly equilateral, with sides which are about 4,000 feet long. The base used may be any one of the sides of this triangle, and the particular side to be used is that which will be most nearly at right angles to the path of the balloon.

FREE-BALLOON FLIGHT IN THE NORTHEAST QUADRANT OF AN INTENSE CYCLONE.

By Lieut. C. LeROY MEISINGER, Signal Corps Meteorological Service.

[Dated: Fort Omaha, Nebr., Mar. 26, 1919.]

At 3:37 on the morning of March 14, 1919, the writer participated in a free-balloon flight from Fort Omaha, Nebr. The balloon had a capacity of 35,000 cubic feet and carried a party of five, piloted by Lieut. Ralph A. Reynolds. Owing to a somewhat gusty east wind, which seemed to bear the balloon down upon the ground, the oscillations of the bag were so severe as to cause the basket to crash into the ground on the getaway, rendering the barograph useless. Nevertheless, the whole experience was one of beauty—the full moon above the fog billows, the sunrise, and finally the landing in the fog. At 9:10 a landing was effected in a field about 8 miles southeast of Geddes, S. Dak.—an air-line distance of 322 kilometers from the starting point.

Table 1 is a summary of the flight:

TABLE 1.—*Record of free-balloon voyage, Mar. 14, 1919.*

Time.	Altitude (altimeter set 0 at Fort Omaha).	Probable direction of travel.	Temperature.[1]	Remarks.
A. M.	*Feet.*		° *F.*	
3:37	(2)	W.	30	
3:47	1,750	W.	30	Above clouds.
3:57	1,750	N.	30	Do.
4:07	1,800	N.	30	Do.
4:22	1,850	N.	30	In clouds.
4:37	1,850	NW.	26	Do.
4:52	1,850	NW.	26	Do.
5:07	1,850	NW.	26	Do.
5:22	1,900	NW.	26	Do.
5:37	1,950	NW.	26	Do.
5:52	1,800	W.	22	Do.
6:07	1,825	W.	22	Do.
6:22	1,650	W.	21	Trail rope touched ground at about 6:30
6:37	[3] 700	W.	28	In clouds.
6:52	850	W.	30	Above clouds.
7:07	700	W.	32	Do.
7:22	900	NW.	32	Above clouds; first appearance of sun.
7:37	900	NW.	[4] 38	Above clouds.
7:52	1,400	NW.	38	Do.
8:07	1,750	NW.	38	Do.
8:22	1,750	NW.	38	In clouds.
8:37	1,600	NW.	38	Do.
8:52	1,000	NW.	26	Do.
9:10 [5]				

[1] Thermometer of cheap commercial make.
[2] Left ground.
[3] Altimeter reset by about 1,100 feet after trail rope touched ground.
[4] Temperature uncertain, as thermometer was not shielded from sun.
[5] Landed 8 miles southeast of Geddes, S. Dak.

First, let us consider the pressure distribution on the morning in question, namely, March 14. (See fig. 1.) There was an area of high pressure over eastern Canada and a low-pressure area centered in northern Colorado. The gradient was quite steep, due to a pressure difference of over 50 millibars (observed difference 1.68 in.) between the two centers. The isobars of the Middle West were almost parallel in a northwest-southeast direction. Because of this steepness of gradient, high winds in this region were to be expected. During the day the center of low pressure moved in a northeasterly direction, and in northern Nebraska there were ver yhigh winds, accompanied in the afternoon by terrific hailstorms and, in several places, by small tornadoes. This leaves little doubt as to the eddying and somewhat turbulent state of the atmosphere in this vicinity.

On the morning of the departure the wind was easterly on the surface and quite gusty. The sky was overcast

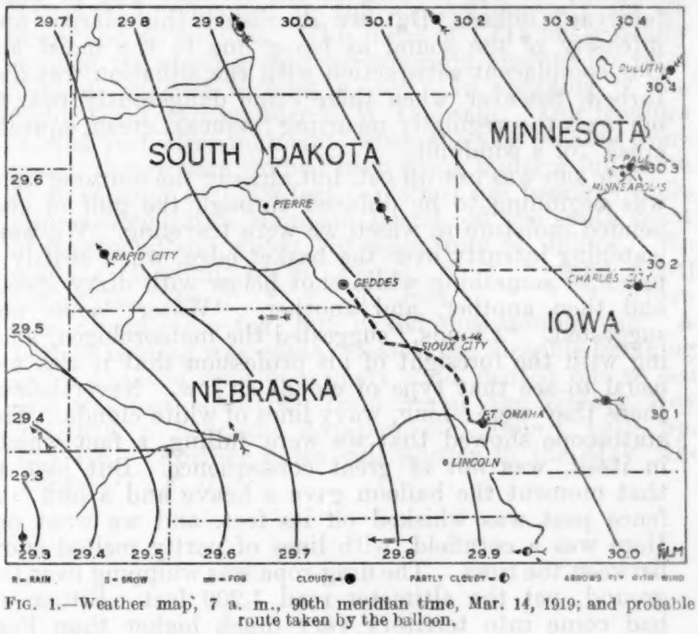


FIG. 1.—Weather map, 7 a. m., 90th meridian time, Mar. 14, 1919; and probable route taken by the balloon.

with a very low stratus sheet, the base of which was not over 300 feet above the ground. As nearly as could be judged, these clouds were moving about 9 meters per second from the east. The balloon, of course, left the ground moving west and maintained this direction while passing into the clouds. Quickly passing through the cloud layer, for it was not very thick, we encountered

a new stratum of air moving in a new direction and with considerably greater speed. The sky above was clear. In the southwest the full face of the moon, orange-colored, beamed over the soft blue-gray fog billows. Our new direction and speed were evidenced by two phenomena:

First, the flags suspended from the rigging suddenly began to whip about quite violently; and

Second, the clouds below appeared to be traveling at a tremendous speed away from us and directly toward the moon.

The first phenomenon, which is very common in ballooning, indicates the turbulence which is present at the interface of two layers of air. The second can be proved to show that we had assumed a new direction, namely, north. It seems probable that the direction of motion of the upper surface of the stratus cloud was toward the northwest; that is, parallel to the isobars, a direction which the gradient wind would take. The apparent movement of the clouds was toward the west-southwest, which could be accounted for by the movement of the balloon northward.

About half an hour after rising above the low stratus cloud, we began to settle into it. More and more frequently we encountered huge mountains of fog, until finally we were completely enveloped by it. Even the gray bag overhead was scarcely to be discerned. One can not conceive of a more perfect picturization of the word "void." Above, below, and on either hand lay an ocean of soft, neutral nothingness. Indeed, the words, "Abandon hope, all ye who enter here," were constantly recalled to our minds. We drifted thus for about two hours and one-half, with the altimeter reading between 1,500 and 2,000 feet.

Yet there was no monotony, for, in spite of the dreary aspect of the surrounding medium, there was a startling clearness to the crowing of the roosters and to other farmyard noises. But we dismissed this clarity and intensity of the sound as being due to the moist air. Our complacent satisfaction with the situation was disturbed, however, when there came dangerously near to our ears the regularly recurring "squeak, creak, squeak, creak" of a windmill.

The sun was not up yet, but already the morning light was beginning to be diffused through the gulf of suspended moisture in which we were traveling. We were watching intently over the basket edge, when swiftly a patch of something white shot below with dizzy speed, and then another, and another. "Water" some one suggested. "Clouds," suggested the meteorologist, adding with the foresight of his profession that it was unusual to see that type of clouds so low. Nevertheless, there they were—long, wavy lines of white clouds. The statoscope showed that we were falling, a fact which, in itself, was not of great consequence. But just at that moment the balloon gave a heave and a jerk. A fence post was whisked off its feet, and we went on. Here was a cornfield, with lines of partly melted snow between the rows. The drag-rope was whipping over the ground, yet the altimeter read 1,200 feet. Either we had come into territory very much higher than Fort Omaha or our altimeter had suffered like the barograph in the getaway. A bag of sand overboard sent us back into the fog. The pilot reset the altimeter by about 1,100 feet and we felt considerably easier concerning our altitude.

By this time the sun was rising, and with its appearance we were permitted to witness such a scene of beauty as no one can dream of who has not explored the wonders of the upper air. It defies description. It was such a scene as Maeterlinck might employ in transporting a mortal to another world. Below lay a gently undulating sea of fog, soft as down and delicately tinted as mother-of-pearl. Above, with apparent motion scarcely perceptible, floated a layer of alto-cumuli opaled by the rising sun, and ever varying in iridiscent splendor. The upper clouds were beginning to dissipate under the sun's rays, and, as they melted away, the sun itself burst forth casting the balloon's shadow far away onto the fog bank, and gave the fog below a softer, rosier, more vaporous appearance. The fog, also, was beginning to succumb to the morning heat.

Our hopes for a little while were high, thinking that the fog would shortly be dispelled by the rising sun. A little bird came winging out of the mist like the dove to the travelers in the ark. After a short visit, he returned to the void beneath and was not seen again. In the southeast and south appeared a great blue bank of threatening strato-cumuli. They were approaching us, or we them, at a terrific speed. This occurred at 7:20 and was accompanied by a rotation of the balloon in such a manner that the sun, instead of being on our right, was now on our left, indicating, perhaps, that we were facing the southwest, whereas, but a few minutes before, we had been facing the northeast. In a short time the sun was obscured by the onrushing clouds, and in the clear space between the smooth-topped fog and the layer of strato-cumuli we found ourselves once more completely isolated from the world or any sign of life.

There is a phase of free ballooning upon which it seems difficult to get light from balloonists; namely, does the trail-rope dangling from the side of the basket afford an axis of rotation for the balloon? Apparently it does. For example, when the balloon is released, it is generally so turned that the trail-rope is on the windward side of the basket. It has been noticed that when the balloon experiences a change of direction the trail-rope continues to follow the balloon; or, more precisely, that the entire balloon turns in such a manner that the rope is on the side from which the wind is blowing. Or, if the lower end of the trail-rope is in a wind of different direction, perhaps the rope will remain on the side of the basket from which the wind is blowing relative to the wind below.

When the sun rose, we were facing the northeast although the balloon was probably moving slowly toward the northwest. The expansion and heating of the gas carried us up and probably into a new current, for at 7:20 we experienced a clockwise rotation through about 210°, as indicated by the position of the sun, so that we now faced the west-southwest. We were now traveling rapidly, probably still from the southeast.

All hope of the fog lifting was now abandoned and a landing was imperative. Being entirely ignorant of our position, however, the valving had to be effected very delicately. We came down slowly, unable to see the end of the trail-rope, so dense was the fog. We felt the rope touch, and, in a moment, patches of snow were seen to slip below with alarming rapidity. We came low enough to see that we were over ice. Afterward we learned that it was Lake Andes, which has a surface of over 30 square miles. Ballast was thrown so that we were soon back in the fog. In a few minutes a second and more successful attempt to land was made. This time we identified a straw stack and a fence and began a very rapid descent. Within 150 feet of the ground there occurred what seemed to be a complete reversal of wind direction, for what we presumed to be the same

straw stack we had seen the moment before came rushing back at us. This point is not clear, however, and there is a difference of opinion among the members of the party. About half an hour after we landed, a thunderstorm broke upon us, giving a heavy precipitation of rain, snow, and hail. The wind during the occurrence of the heavy precipitation seemed to come from the east-southeast. It is possible that we were caught in the squall ahead of the thunderstorm, and this may have been responsible for the capricious conduct of the balloon just before landing.

It may seem that this discussion of our probable path is based upon rather uncertain evidence. Yet, in spite of the fact, I feel very confident of the conclusions. Apparently the distance traversed by the balloon was about 400 kilometers. This yields an average speed of about 20 meters per second. About 12 hours after the journey began, the Drexel, Nebr., Aerological Station obtained a wind of 31 meters per second from the south-southwest at an altitude of 500 meters. Wind speeds of from 10 to 15 meters per second were recorded at the Ellendale, N. Dak., Aerological Station during the time that we were in the air, although we do not have data from that station for the altitudes at which the balloon rode. The projection of our path, then, seems entirely in accord with all the observed phenomena of the trip. There is a very decided charm about being suspended in the air, especially when one is uncertain as to his location, and when one does not know his speed. This journey did more than provide those thrills; it enabled us to actually penetrate and become a part of the wind circulation of a strong cyclone.*

WEATHER DURING SOME NOTABLE AIRSHIP VOYAGES.

(1) In an account of the 4,500-mile trip of the German Zeppelin, *L 59* from Bulgaria to the Sudan and return, one of the crew makes the following mention of the weather:

"While we experienced on the afternoon of November 23 [1917], at an altitude of 7,500 feet [over the Libyan desert south of the oasis of Farafrah], a temperature of 32° C., and wore tropical uniforms, ten hours later we had to put on our leather suits, as the temperature had dropped to 12° C. [near (?) the Nile Delta]."—Abstract from Aviation, Mar. 1, 1919, pp. 158–159.

(2) In a trip of a large dirigible from Rome to England, October 29 to November 1, 1917, much unfavorable weather was encountered. From Rome to Marseilles, "very bumpy weather was experienced over Civita Vecchia [west coast of Italy], and later on a rainstorm was encountered." In the stage from Marseilles to Paris "there was a head wind against which they made poor progress."—Abstract from Aviation, Mar. 1, 1919, pp. 158–159.

(3) "In spite of encountering rain, high winds, snow, and extremely low temperatures in cruising up and down the [Atlantic] coast [of the United States], February 26–28, 1919, Ensign C. W. Tyndall established a new endurance record for the nonrigid type of balloon, remaining aloft for 33 hours and 6 minutes."—Aerial Age Weekly, Mar. 3, 1919, p. 1265.

(4) A record airship voyage, and what is described as one of the most notable cruises ever undertaken by airship, was accomplished over the North Sea by *N. S. 11*, one of the British non-rigid type. The voyage took the form of a circuit, which embraced the coasts of Denmark, Schleswig-Holstein, Heligoland, North Germany, and Holland, and the most unfavorable weather conditions were met with. The total length of the round trip was 1,285 miles, and the time occupied was 40½ hours.

"The important point about this cruise is not only the distance covered and the long time the vessel was afloat, but her airworthiness in conditions of the most trying character. Starting from the Firth of Forth at 3.45 p. m. on March 18, the first 280 miles were covered easily with only a departure of about a mile from her course. Gradually the wind grew stronger and rougher, and when one engine broke down it seemed doubtful whether the ship could reach the English coast. When, however, it did finally reach the north foreland, petrol was running short owing to the necessity of running at full power earlier in the voyage, and one engine only was running, this on five cylinders out of six."—Aeronautics, Mar. 27, 1919, p. 328.

(5) The naval dirigible *C-5*, which made a successful flight from Montauk Point to St. Johns, Newfoundland, May 14–15, remained in the air continuously for 25 hours and 40 minutes. This flight of 1,115 miles nearly equaled the above record for non-rigid airships for total distance covered without a stop. In speaking of the flight, Lieut. Commander E. W. Coil said: "Our troubles started just after midnight, when the sky became overcast. Before then we had been flying under a full moon at an altitude of 1,000 feet. We lost our bearings while approaching Little Miquelon Island, off the south coast of Newfoundland, about 170 miles from St. John's. We made a 'landfall' at St. Pierre, * * * [and went] 'cross lots' to * * * St. John's. * * * There was considerable fog, but it did not trouble us." A perfect landing was made. Later, the dirigible breaking away a second time in a gusty wind, drifted out to sea and was lost.—Abstract from Aerial Age Weekly, May 26, 1919, p. 533; and Aviation, etc., June 1, 1919, pp. 475–476. (Further notes will appear in the May Review.)—*C. F. B.*

* The meteorological results of the flights of two balloons, starting from Fort Omaha, at the same time, one attempting to hold an altitude of 5,000 feet, and the other 10,000 feet, will be published in a later issue of the Review.—Ed.

HOT WINDS AT TAMPICO, MEXICO, APRIL 6 AND 7, 1919.

By S. A. Grogan.

[Dated: Mexican Gulf Oil Co., Tampico, Mexico, Apr. 15, 1919.]

On April 6, 1919, we had a hot, dry southwest wind from 11 a. m. to 3 p. m. (Tampico time) with a maximum temperature, 93.5° F., the highest since June 19, 1918. On April 7, from 11 a. m. to 1:15 p. m., the hot wind blew again, with a maximum temperature of 99° F. at 1:15 p. m., when the wind changed to SE., and there was a drop of 16° in five minutes. This maximum temperature is the highest on our record, which dates from October 12, 1917. Figure 1 shows tracings from the thermograph record, corrected to the thermometer readings, and from the barograph here, April 5 to 9, 1919. Table 1 gives in detail the observations made on April 7.

Table 1.—*Weather Observations, Tampico, Mexico, April 7, 1919.*

Observation of—	Tampico time.		
	6.30 a. m.	12.15 p. m.	6.30 p. m.
Dry thermometer	71.5° F.	96° F.	77° F.
Wet thermometer	69.5° F.	67.5° F.	72° F.
Dewpoint	68° F.	49.5° F.	70.5° F.
Relative humidity	90 per cent.	21 per cent.	79 per cent.
Vapor pressure	0.684 inch.	0.353 inch.	0.732 inch.
Barometer	29.71 inches.	29.71 inches.	29.69 inches.
State of weather	Clear.	Clear.	Cloudy.
Wind blowing from	S.	SW.	SE.

A similar hot wind has occurred only once before to my knowledge. On January 14, 1918, a hot, dry southwest wind prevailed from 2 p. m. to 3:20 p. m. (Tampico time) with a maximum temperature of 87° F., and a sudden drop to 75° F., when the wind changed to the northeast.

I have had several inquiries as to the cause of the hot winds of April 6 and 7, and I have given as the probable cause that which is credited with forming the famous "Chinook" winds of the western Great Plains. We have had very little precipitation in this vicinity this year (6.65 inches to April 8), but the country to the south and west has had an abundant rainfall; and so I am of the opinion that the warmness and dryness of the wind could not have been caused by having blown over hot and dry land. The Sierra Madre mountains [eastern escarpment of the plateau] are 60 miles west of Tampico.

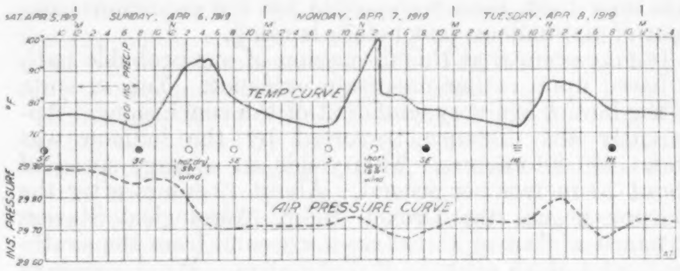


Fig. 1.—Weather at Tampico, Mexico, Apr. 5-9, 1919.

DISCUSSION.

In view of the large low-pressure area centered not far north at this time, it is possible that the wind which reached Tampico so hot and dry had been robbed of much of its moisture on passing up the west flank of the Mexican plateau, and then had been heated chiefly by compression on its eastward descent. The conditions observed at Tampico could have resulted if air nearly saturated at 50° F. had descended the 7,000 feet from the plateau to Tampico. In addition to the 37° F. rise in temperature which would have resulted from compression alone, it probably would have warmed 10° F. in passing over 60 or more miles of coastal plain during the morning. The fact that the three occurrences mentioned took place only during the middle of the day would seem to indicate that at other times, if there is a forced descent of air from the plateau, such heated air can not penetrate to the surface. The convectional mixing of the lower air strata, coupled with the diurnal warming of the air en route, seem to be necessary to make such foehn winds felt on the Gulf coast.—*C. F. Brooks.*

TORNADOES IN EASTERN NEBRASKA, APRIL 6, 1919.

By G. A. Loveland, Meteorologist.

[Dated: Weather Bureau, Lincoln, Nebr., May 22, 1919.]

An area of low pressure of unusual energy, 29.2 inches, was central in southwestern Nebraska or eastern Colorado on Sunday, April 6. (See fig. 1.) In the evening, three tornadoes occurred in eastern Nebraska. One of these was near Elmwood (25 miles SW. of Omaha) at 6 p. m. (90th meridian time). A second, near Madison (90 miles NNW. of Omaha) at 6:30 p. m. damaged 6 farms. A third occurred at Omaha at 7:30 p. m., and is said to have damaged 400 houses and caused a loss of a quarter of a million dollars.

The tornado near Elmwood was observed by a number of people, and the accompanying unusually good photographs (figs. 2 to 7) were made of it. The path of the tornado was narrow, most of the distance less than 300 feet in diameter, and it lay in a general direction a little west of north. At the same time, however, the upper portion of the funnel where it joined the general cloud base was moving toward a point a little east of north. The funnel increased in length, and finally an apparent loop, due to perspective, developed. This loop shows somewhat in figures 2, 6, and 7. The funnel dissolved, but the dust cloud or lower portion of the funnel continued for a few seconds after the upper part had disappeared, and moved with devastating force for about three-fourths of a mile. The whole length of the tornado path was only about 7 miles, and the tornado made it in about 10 minutes. No lives were lost, but several farm houses were destroyed and others injured. Further details are given in the following extracts from observers' accounts.

Mr. W. A. Wood, of Weepingwater, Nebr., who took the photographs, figures 3 to 7, gives the following description of the local weather, and the appearance of the funnel cloud:

"Upon the day of the Elmwood tornado, I observed that there was every indication of rain, as the sky was entirely overcast with clouds and the weather was quite humid. About noon, however, the sky began to clear,

FIG. 2.—The tornado was photographed by G. B. Pickwell, who was very near its path. The upper picture, *a*, was the upper portion of the funnel, and was taken first. Immediately afterwards the lower portion of the funnel was photographed, and shows in *b*.

FIGS. 3 and 4.—Successive photographs of the tornado taken by W. A. Wood from the southeast.

FIGS. 5, 6, and 7.—Successive photographs of the tornado, taken by W. A. Wood from the southeast. In figures 6 and 7, note the vertically elongated form of the detached cumuli, which are characteristic of local convection intensified by a strong vertical temperature gradient. (See discussion.)

and in the afternoon we had every indication of continued good weather, were it not for the low pressure area in the southwest.

"Toward the latter part of the afternoon, storm clouds began to form, and in a short time it began to look like rain. At the base of what appeared to be a very ordinary cloud there was a small khaki-colored formation, that in a few moments began to taper, and which finally sent down a tiny line the color of blue smoke. This streamer made immediate connection with the earth and was the commencement of the tornado proper.

"This must have been a freak storm as the tail was very slender and resembled a rope dangling from the clouds. The pictures (figs. 3 to 7) tell the story better than I can write it.

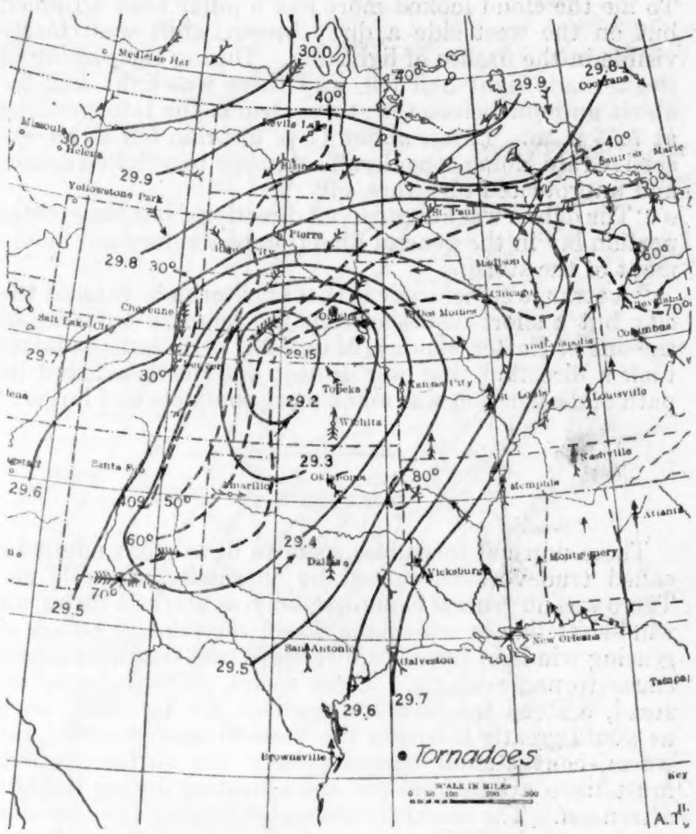


FIG. 1.—Weather map, Apr. 6, 1919, 7 p. m. (90th meridian time). The temperatures at North Platte, Nebr., and Concordia, Kans., less than 200 miles apart, were 46° F. and 76° F., respectively. An extreme range of 54° F. occurred between Cheyenne, Wyo., temperature 26° F., and Fort Smith, Ark., temperature 80° F. The arrows fly with the wind, and the number of barbs indicate the wind velocity in Beaufort numbers.

"It seems that the dissolution of the cloud was brought about from the fact that the progress of the lower part was slower than that of the upper, so that, finally, on being elongated to 1¼ miles, it was pulled in two nearly at the center.

"The lower part continued for some time, peaked at the top. There was entirely blue sky beneath the main cloud, hence my advantage in taking the photos. Hail preceded the tornado."

Mr. W. A. Rocky, an instructor in the department of geography in the University of Nebraska, happened to be in the immediate vicinity of the tornado, and made some excellent observations of it. The following notes are from his detailed description.

"The Elmwood tornado * * * extended only for a distance of about 7 miles, from somewhere near the west edge of sec. 9, T. 9 N., R. 10 E., 6 p. m., to the extreme southeastern corner sec. 6, T. 10 N., R. 10 E. For the first 4 miles of the course it traveled almost due north, with but little variation. In its last 3 miles it followed a course of about north 27° west. It took approximately 10 minutes to go 7 miles, a rate of 40 miles per hour. It was preceded by rain and hail, which was very heavy to the east of it, decreasing in amount to the westward. The storm did not greatly cool the atmosphere. Practically no rain fell more than half a mile west of the tornado track. There was no precipitation at all on the last mile of its course, either before or after its occurrence. The wind direction and velocity, about southeast 20 mis./hr. as nearly as could be observed, was constant during the entire hour of this storm. The tornado was accompanied by a very loud roaring and a sound of rushing air. * * *

"When first seen the base of the funnel was in the air, traveling like a kite's tail. Within 30 seconds it had reached the ground about 4 miles away. It was then in the southeast. It was observed from Elmwood for probably 6 minutes. * * *

"The funnel cloud during its entire existence appeared almost white, much as a column of steam. The sun's rays did not strike it at any time. Throughout its lower half it probably did not exceed 100 feet in diameter. The upper half of the funnel increased in size toward the top, and where it merged into the dark storm clouds above it probably had a diameter of 300 feet. As judged by the writer, the funnel had a length of from 1,000 to 1,500 feet, becoming longer toward the last. When first seen the cloud was inclined toward the north about 45° from vertical, the base dragging along in the air, and there was no dust cloud. The whirling of the cloud itself could be very clearly seen. Soon after the funnel struck the ground a cloud of dust and débris arose about 200 to 300 feet although the central core (white cloud) could be clearly seen through the dust envelope. * * * This outer cloud of dust was thickest near the ground, gradually thinning upward. The density and size of the dust cloud changed greatly, probably due to the varying looseness of the soil. About 300 feet above the ground no dust was seen at any time. Débris was seen flying in the upper, thinner portion of this dust cloud during the entire period of its existence. After the base of the funnel reached the ground the base appeared to increase its velocity, decreasing the angle of inclination of the funnel.

"During about the fourth mile of its course the funnel began to lean to the east as well as to the north, and by the end of its fifth mile the summit of the cloud was at an angle of about 45° from vertical, and northeast from the base of the cloud. During the last 2 miles of its course the base continued to veer westward, the funnel appearing to move more nearly northward, thus still further increasing the angle of inclination. During these last 3 miles the funnel gradually became more slender, and in several stages developed an apparent loop. This loop began in a very sharp, double curve or crook. It was always on the rear side of the advancing column and above the column, while the base trailed behind the summit but ahead of the loop. After the formation of this loop it slowly rose toward the summit of the cloud, which it reached at about the instant the cloud dissolved. During all of the final moments of the cloud the funnel was constantly decreasing in diameter. It is certain that toward the last some parts of the funnel near the base had a diameter not exceeding 25 feet.

"The dissolution of the funnel occupied a period estimated at not exceeding 10 seconds. Its disappearance was almost simultaneous from base to summit, much like the disappearance of steam when escaping into cooler air. * * * The surrounding rapidly revolving dust cloud continued on alone for a distance of three-fourths of a mile, apparently undiminished in size and velocity. It then crossed a draw probably 60 feet lower than the uplands, the whirling dust cloud suddenly broke, and, except for a straight cloud of dust, continuing for another fourth of a mile northwestward, there was no further evidence of a strong wind.

"The funnel cloud, which was at all times long and slender, appeared white as viewed by the writer (its western face). To Mr. Pickwell, who looked from the south and southwest, it appeared black near its summit, becoming lighter downward, with its base a very light gray. To Mr. W. A. Wood, 4 miles or more northeast from the cloud, it appeared dark its entire length. The outer surface of the funnel cloud was very clear cut near the base, becoming more fuzzy in appearance near the summit. The revolving of the funnel cloud could be very distinctly seen in all parts, certain sections sometimes having a fibrous or stringy appearance. The funnel appeared to lengthen or stretch very materially during the latter part of its course.

"During the progress of the cloud the large amount of material carried into the air from farmsteads just south of the Missouri Pacific Railway was distinctly seen. One building, apparently entire, was lifted about to the upper level of the dust cloud. While poised at that highest level all parts of the building appeared to come apart, flattened into a single horizontal plane, then scattered as a deck of cards thrown in the air. Trees were seen entire and broken. Parts of buildings were seen in the air at almost any moment during its course. The usual width of the devastated path was from 200 to 300 feet, and its borders were clearly marked. * * *"

The following is a report of the Omaha tornado by Mr. M. V. Robins of the Weather Bureau.

"A small tornado that formed a short distance southwest of Omaha struck the city limits about 7:30 p. m. (90th meridian time), April 6, 1919, and moved in a north-northeasterly direction in the city over a path varying from 200 to 600 feet in width and between 3 and 4 miles in length. The funnel left the ground for short stretches, at places skipping blocks. After the tornado funnel had left the ground permanently, the wind was violent enough to do some damage even beyond the city limits north of Omaha as the storm moved on. The explosive effect was in evidence in a number of instances." * * *

"No loss of life occurred or has resulted from injuries received, but probably 20 persons received injuries, a few serious, but mostly they were slight. One house that contained eight people, three on the first floor and five in the basement, was completely demolished, but not one of the occupants was even scratched. Fortunately, the path of the tornado was through a district part of which was not thickly settled, hence the comparatively small property loss (about $250,000) and few casualties.

"Some observers said that there was a violent commotion among the very dark coppery clouds in the southwest just before the funnel appeared; others that the storm cloud which swept the earth was more like a pillar than a funnel, and a few reported that tongues of lightning flashed from its center. I was on my way home from the car line, and it later developed in the immediate path of the storm, when I heard the unmistakable roar as of a great engine, and saw the dark mass rushing in my direction. I ran for home hoping to reach it in time to get my family into the basement, but by the time I arrived the storm had passed a few hundred feet to the east. At my location there were violent gusts, and even at greater distances from the storm path windows were blown out and slight damage was done to shingle roofs. To me the cloud looked more like a pillar than a funnel; but on the west side a dirty brown whirl was clearly visible in the flashes of lightning. During the passing of the tornado light hail fell, and there was light rain for about an hour before the storm struck, the latter ending at 7:55 p. m. Later, about 11 p. m., rain fell at an excessive rate, doing considerable damage to wrecked homes and unprotected furniture, etc.

"The débris was strewn in all directions, but the greater portion lay in the general direction of the forward movement of the storm.

"A strange coincidence is that this tornado entered the city but a short distance from the point of entrance of the one of Easter Sunday, March 23, 1913, but the latter took a direction that was almost due northeast and its path of destruction was much more complete and larger."

DISCUSSION.

These unusual tornadoes seem to have what might be called true vortices caused by thermally unstable air. There was no general cloudiness such as marks a turbulent wind-shift line in which the direct mechanical action of grazing winds of opposite directions and densities might cause tornadic whirls. There seems to have been, instead, a steep temperature gradient not far aloft, such as would greatly intensify the vertical movement of the warm, convectional currents from the surface, which must have arisen from the sun's heating during the fair afternoon. The markedly elongated form of the cumulus clouds seen in the background of some of the pictures is indicative of such strong local convection which has become intense since condensation is retarding the cooling of the rising air.

The cold air necessary to have formed such a strong gradient aloft probably came from the very cold side. Over this region this cold wind was probably westerly, as the intermediate and upper clouds in the morning were moving from the west. The surface SE. wind would explain the movement of the lower part of the tornado, and the W. cold wind aloft would explain the rapid northeastward movement of the parent cloud and the fall of rain and hail generally east of the track.

—*C. F. Brooks.*

TORNADO IN SOUTHERN ALABAMA, MARCH 5, 1919.

By P. H. Smyth, Meteorologist.

[Dated: Weather Bureau, Montgomery, Ala., May 5, 1919.]

The weather map on the morning of March 5, 1919, is shown in figure 1. The evening map, 12 hours later, showed the well-defined trough of low pressure extending from the mouth of the St. Lawrence to western Florida. As shown on the map of southern Alabama (fig. 2), early in the afternoon of March 5 a tornado developed in the southwest portion of Escambia County and moved northeast by east to the central-eastern portion of Barbour

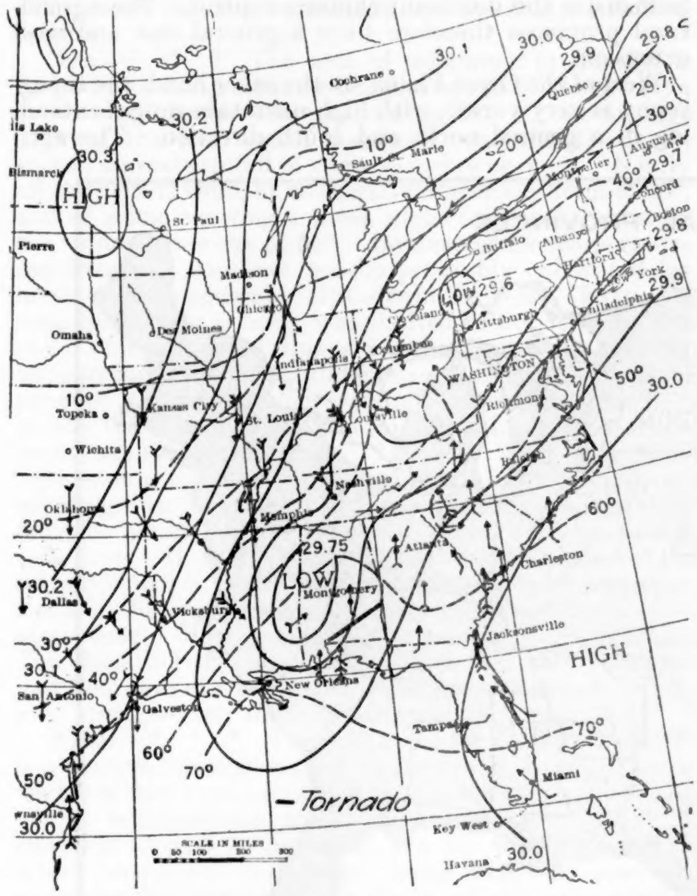


Fig. 1.—Weather map, Mar. 5, 1919, 7 a. m. (90th meridian time). The arrows fly with the wind, and the number of barbs indicate wind velocities on the Beaufort scale.

County. The path of the tornado was from 130 to 140 miles long and from probably a hundred or more yards to 2 or 3 miles wide. It was reported at Flomaton, Escambia County, between 12:30 p. m. and 12:40 p. m.; at Pollard, 6 or 8 miles northeast of Flomaton, at 12:45 p. m., reached the extreme southern portion of Crenshaw County at 1:30 p. m. and Eufaula, Barbour County, where it was most destructive, at 2:45 p. m. The tornado does not seem to have passed over into Georgia.

At Flomaton the path of greatest destruction was 75 to 100 yards wide. The funnel-shaped cloud was observed. Trees on the north side of the path lie toward the south, and on the south side, northeast by east. One small building was completely destroyed, one house unroofed, two other houses blown off of their foundations, and the passenger station of the Louisville & Nashville Railroad Co. damaged to the extent of $700 to $1,000. Only one person was reported injured.

At Pollard the path of greatest destruction was about 300 yards wide. The funnel-shaped cloud was observed. Trees lie toward the northeast on the south side of the path and also in the center of the path, but on the north side, although the general direction was northeast, there was more of a mixup. The damage to property at Pollard is estimated at $20,000, and two persons were injured.

The cooperative observer at Troy, Ala., reports that in the southeast portion of Pike County, the Friendship M. E. and Shady Grove Baptist Churches were demolished and that a 12-year-old girl was killed. Damage to barns, etc., was considerable.

Six miles south of Brantley, Crenshaw County, five or six persons were injured.

At Eufaula the tornado advanced from the southwest toward the northeast. No one at Eufaula noticed a funnel-shaped cloud. The general direction of trees on

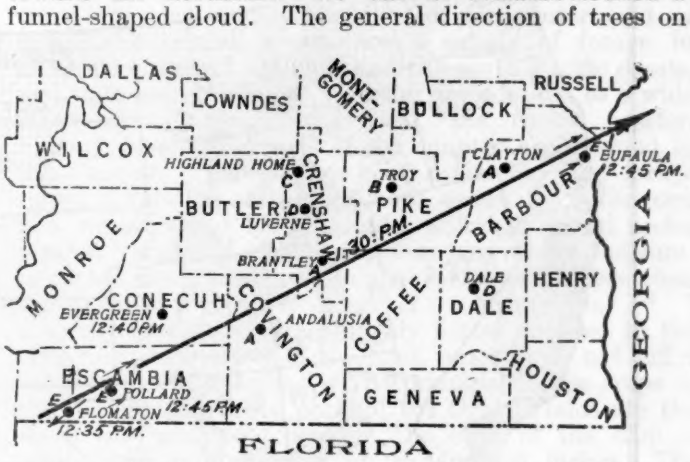


Fig. 2.—Tornado path in southern Alabama, Mar. 5, 1919. A, no damage reported; B, tornado reported southeast of Troy; C, rain and strong, driving wind; D, no storm reported; E, in path of great destruction.

the north and south sides and in the center of the path was toward north of east, though there were a few exceptions. The path of greatest destruction was 1½ to 2 miles wide. The money value of property destroyed is estimated at from $150,000 to $200,000. Drs. J. B. and G. W. Whitlock were considerably injured when their building collapsed. The Catholic Church, a brick structure, located about one-half mile west of this building, was also destroyed. Three brick storehouses were completely wrecked, and of nine persons in them four were killed and five injured. Several lightly constructed buildings in the residence section also went down, but no one was seriously injured. Hundreds of trees were blown down, and practically every tin roof in the business section of the town was more or less damaged.

Figure 2 shows the path of the tornado, the time of occurrence at the several places, and the direction the trees were blown along the path of the storm.

THE LARGER RELATIONS OF CLIMATE AND CROPS IN THE UNITED STATES.[1]

By Prof. R. DeC. Ward, Harvard University.

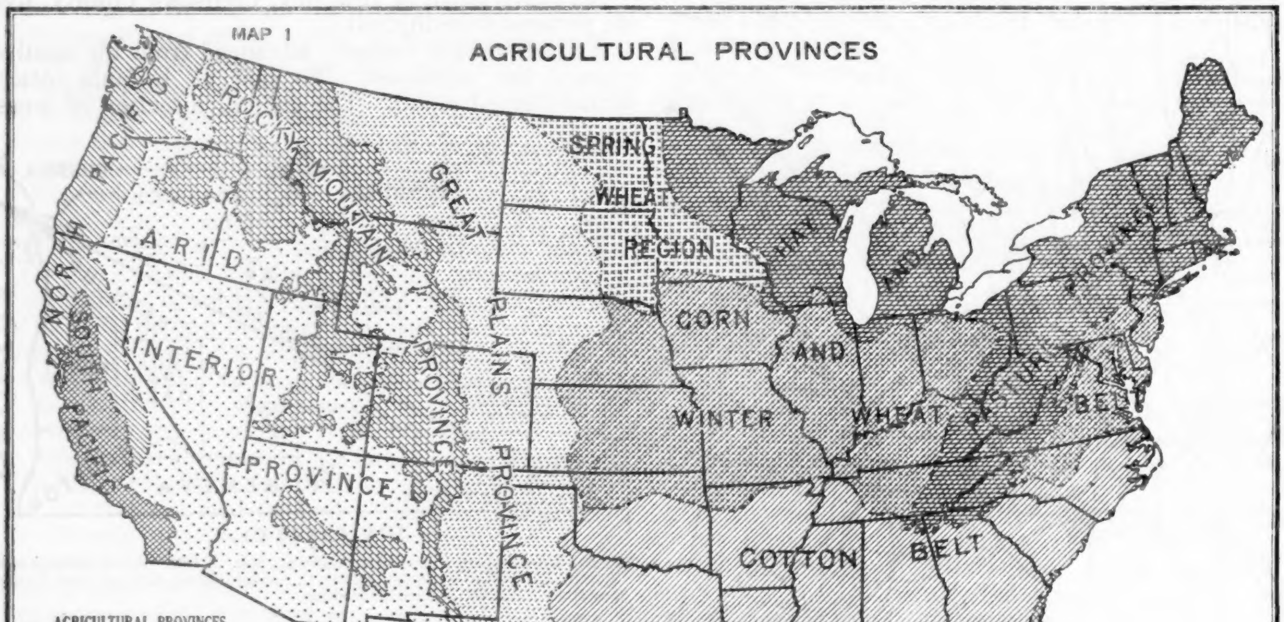
[Abstract from Quarterly Journal Royal Meteorological Society, January, 1919, pp. 1-19.]

With their wide range of climatic types, and their great variety of vegetable products, the United States offer an unusually interesting field for the study of the relations between climate and crops. * * * Climate is but one of the many controls which determine the present geographical distribution of the staple crops, but it is fundamental. Soil, the kind of seed, methods of cultivation, population, transportation, and other factors play a part in a relation which is inevitably so highly complex that great caution is necessary in the endeavor to express it in terms of one, or more, of the climatic elements.

The map here reproduced (fig. 1) is based primarily upon the distribution of the principal crops and upon the types of farming. The country is conveniently divided into two major divisions, separated by * * * the "dry farming-line." The half of the country east of this line has sufficient rain in normal years, and produces annual summer crops cultivated by ordinary farming methods. The western half of the United States, with generally inadequate rainfall (except on the north Pacific coast and in parts of California and of the northern Rocky Mountain district), contains only limited areas where ordinary farming of the eastern type can be practiced. The West is a region of irrigation, of dry farming or grazing. In special localities winter crops are raised Both eastern and western halves may be subdivided into five agricultural provinces. The eastern half is essentially a lowland, interrupted toward its eastern margin by the plateaus and mountains of the Appalachian system, all of moderate elevation. Hence latitude, i. e., temperature, and not altitude [except in the Appalachians] is the dominant climatic control. The agricultural provinces therefore have a general east and west extension.

West of the Great Plains, on the other hand, the topography is very varied, with high mountain ranges extending in a general north and south direction. The agricultural provinces also extend roughly north and south. Rainfall is here the critical factor, and rainfall is largely determined by the topography. Under the control of the varying conditions of rainfall, temperature, altitude, soil, and economic factors, the crops in this western section are very varied, and often extremely localized. There are no great belts distinguished by certain dominant crops as in the East. A detailed map of crop distribution in the West is therefore very patchy, the patches usually corresponding to districts of local irrigation. The names of the agricultural provinces in the West are not derived from the characteristic crops, but from location or topography.

If we consider each of the major crops it is found that the boundaries of the most important regions where they



AGRICULTURAL PROVINCES

PROVINCES	LAND AREA	LAND IN FARMS 1910		IMPROVED LAND IN FARMS 1910		LAND IN CROPS 1910	
	ACREAGE	ACREAGE	PER CENT OF AREA	ACREAGE	PER CENT OF AREA	ACREAGE	PER CENT OF AREA
Southern Coast	54,244,000	11,816,000	21.8	3,350,000	6.2	2,253,000	4.2
Cotton Belt	301,331,000	196,793,000	65.3	89,182,000	29.6	66,298,000	22.2
Corn and Winter Wheat Belt	305,453,000	264,524,000	86.6	197,453,000	64.6	131,215,000	43.0
Hay and Pasture Province	251,360,000	146,153,000	58.1	82,710,000	32.9	49,596,000	19.7
Spring Wheat Province	74,215,000	61,490,000	82.9	48,178,000	64.9	36,855,000	49.7
Great Plains Province	298,803,000	112,486,000	37.6	26,233,000	8.8	15,059,000	5.0
Rocky Mountain Province	185,107,000	29,477,000	15.9	11,827,000	6.4	6,978,000	3.8
Arid Interior Province	330,612,000	22,978,000	7.0	6,522,000	2.0	3,671,000	1.1
South Pacific Coast	44,970,000	22,489,000	50.0	9,819,000	21.8	4,797,000	10.7
North Pacific Coast	57,156,000	19,586,000	18.5	3,173,000	5.6	1,794,000	3.1
United States	1,903,251,000	878,792,000	46.2	478,447,000	25.1	318,516,000	16.7

Fig. 1.—Agricultural provinces of the United States. Yearbook U. S. Dept. Agr., 1915, p. 335.

[1] Based largely on a study of the following publications: "Geography of the World's Agriculture," by V. C. Finch and O. E. Baker, Office of Farm Management, Washington, D. C., 1917; "A Graphic Summary of American Agriculture," by M. Smith, O. E. Baker, and R. G. Hainsworth, Yearbook U. S. Dept. Agr., 1915, pp. 329-403; "A Graphic Summary of World Agriculture," by V. C. Finch, O. E. Baker, and R. G. Hainsworth, Yearbook U. S. Dept. Agr., 1916, pp. 531-553.

are cultivated coincide more or less closely with certain isotherms of average seasonal temperature, or with certain isohyets of average annual rainfall. This correspondence does not necessarily mean that the given seasonal temperatures or annual rainfalls are the factors responsible for the locations of these boundaries, although undoubtedly it is the case that certain temperature features, such as the occurrence of low temperatures unfavorable for the growth of the crop, and certain rainfall characteristics, such as the seasonal distribution of rainfall, the frequency of droughts, or the frequency of occurrence of rains of different intensities, all of which are related to the average conditions coinciding with the crop boundaries, are the true controlling factors.

Corn.—* * * The area of maximum production is limited by a mean summer temperature of 70° to 80° F.; a mean night temperature exceeding 58° F.; an average growing (frostless) season of about five months (150 days), and an annual rainfall of 25 to 50 inches or more. Nearly all the corn is south of the mean summer isotherm of 66°, and of a line showing a mean night temperature during the summer months of 55°. Because of its temperature requirements, corn can not be profitably cultivated far north, or at considerable altitudes in the West. Extended corn cultivation is fairly well limited in the West by the mean summer rainfall line of 8 inches, but if the summer temperature is over 70°, and evaporation is not excessive, an even smaller summer rainfall will suffice. * * * In the West, as a whole, the rainfall is too light and the nights are too cool for corn. * * * Where the growing season is too short, or the temperature too low, corn is widely grown for silage. The summer rainfall, however, must be about 7 inches or more. Corn is a very profitable crop. It therefore tends to become dominant in regions where it finds the climate best suited to it, especially if the competing crops require farm labor at the same time. Corn is widely grown in the "cotton belt." The climatic range of cotton, however, is much more limited than that of corn, and cotton is a tremendously profitable crop, so corn there becomes subordinate. * * *

Wheat.—* * * The mean winter isotherm of 20° is a general limiting control on the north, although some winter wheat grows in the Red River Valley, where the winter temperatures are a good deal lower. * * * Between 15 and 30 inches of rain are found where the wheat production is densest. Some wheat is, however, grown by dry farming where the mean annual rainfall is 10 inches or even less. * * * The damaging effects of rusts in the moister regions, especially if the wheat can not be made to mature early in the summer; the likelihood of rain interference with harvesting operations; competition with cotton, and other factors limit the great winter wheat region on the south at about the northern edge of the cotton belt.

* * * A mean summer temperature of about 58° F. determines the northern boundary of spring wheat. This isotherm [in the United States] is found only in the mountain area of the West. * * * With respect to the chemical composition and quality of wheat, climate has more influence than soil, but soil has a marked influence upon the permanency of wheat production in any given area.

Cotton.—* * * The mean summer isotherm of 77° F. marks fairly closely the northern, and a mean annual rainfall of 23 inches the western boundary. The average length of the growing (frostless) season is 200 days (Apr. 1 to Nov. 1), and in four-fifths of the years is more than 165 days. Warm and moderately moist weather is most favorable from April to August, while cool and dry autumns improve the quality and facilitate the picking. Too much rain in the picking season injures the lint. Thus, an important climatic element in cotton picking is the way in which the spells of dry weather are grouped. * * *

Oats, barley, and rye.—A cool, moist climate is the best for oats. The winter-oat region of the East, where most of the crop is fall-sown, is in the southeastern section, its northern boundary being about along the mean winter isotherm of 35° F.[1]

In the most important barley districts no month during the growing season has a mean temperature over 75°. In high parts of Colorado, barley grows * * * with much lower temperatures and not infrequent frosts. In southeastern California barley is raised where the mean summer temperatures are over 90°. The chief barley regions of the country have somewhat less than 35 inches of rain a year. In California, the mean annual rainfall is less than 10 inches.

Where rye production is greatest the mean summer temperature is about 70° * * *

Hay, forage, and pasture.—Hay, forage, and pasture crops are very widely distributed, for winter cold or insufficient rainfall necessitate a supply of forage in all sections except the Gulf and the north Pacific coasts, and their many different varieties are adapted to a wide range of climates. In general, the cooler, wetter, rougher, less fertile parts of the country are devoted to these crops. There is, however, much hay and forage raised in rotation with other crops, especially in the corn and winter-wheat belt. Alfalfa, although grown under a great variety of conditions, does best where the summers are not rainy, and in the southwest. Less than 6 per cent of it comes from east of the Mississippi.* * * Timothy and clover are not only better adapted to the crop rotation systems of the East, but also do not suffer much from winter-killing. The principal forage crops of the hot and droughty parts of the Great Plains are the Kafir corn and milo maize. The bulk of the crop is within the rainfall lines of 15 and 30 inches. The northern limit of Kafir is the mean summer isotherm of about 75°; that of milo, about 70°.

Sugar.—Sugar cane raised commercially for sugar comes almost entirely from the lower delta of the Mississippi River, in Louisiana, where the rainfall is heavy (50 to 65 inches), and destructively low temperatures are rare. Sugar beets, on the other hand, come from the northwestern margin of the corn and winter wheat belt, and from local areas in the West, especially in southern California. Profitable use of beets for sugar is, on the whole, limited to regions whose mean summer temperatures are below 72°.

Rice.—Rice needs so much water that it is grown mostly on the moist river plains of the southern coastal plain and Mississippi flood-plain and delta lands. In Louisiana, rice needs water amounting to 0.5 inch of rainfall daily for three months, or 45 inches. Half of this water is supplied by irrigation.

Vegetables.—Vegetables are raised as near to market as the climatic conditions permit. In many cases hothouse vegetables of the North can compete successfully with the early vegetables grown in the usually frost-free southern coast.

Fruits.—Temperature is usually the controlling factor in the distribution of the different kinds of fruits. The citrus fruits come from the Gulf coast region and

[1] See fig. 40, p. 35, Geography of the World's Agriculture. [By V. C. Finch and O. E. Baker, Office of Farm Management, U. S. Dept. Agr., Washington, D. C., 1917.]

California, where killing frosts are rare enough to make the culture profitable in the long run, especially if orchard heating is practiced at critical times. Peaches are raised extensively in the South and on the leeward shores of Lakes Michigan, Huron, and Erie, where killing winter temperatures and frosts after flowering are infrequent. Apples, being hardier, are raised farther north, though in apple culture, valley slopes and leeward (eastern) shores are favored. Pears and cherries are intermediate between peaches and apples.

Live-stock.—Live-stock raising is controlled mostly by rainfall, though the temperature limitations imposed on the distribution of field crops enters also. Hogs thrive where the corn grows; dairy cows are most numerous farther north, where there is the corn silage. Cattle are raised in the general hay and pasture regions, and, in relative importance for the regions involved, hold sway particularly where field crops can not well be raised. In the arid parts of the West the cattle can get some sustenance on the plains and mountains, but the forage (mostly alfalfa) from the irrigated patches must supplement this generally meager and discontinuous supply. In the driest parts, sheep can live where cattle can not.

It is usually obvious that the climate is essentially the basis for the general type of farming at any place. There is the "wet farming" of the eastern half of the country, where the rainfall is generally sufficient for the crops that are to be raised, and where, therefore, the temperature determines what can be raised, and the topography and soil limit the local distribution. The dry farming of the Great Plains and of other parts of the West relies on conservation of what rain there is by limiting evaporation from the soil. In some places, as in eastern Washington, two years' rainfall is needed for one good crop of wheat. The irrigation farming of the arid parts of the West is necessitated by the dryness of the lowlands, but is rendered possible by the rainfall precipitated on the mountains which keep the moisture from reaching the valleys to leeward.

A comprehensive bibliography closes Prof. Ward's paper.—*C. F. B.*

MINIMUM TEMPERATURES SUSTAINED BY APRICOTS DURING MARCH, 1919, IN THE PECOS VALLEY, N. MEX.

By CLEVE HALLENBECK, Observer.

[Dated: Weather Bureau Office, Roswell, N. Mex., May 17, 1919.]

It has been a matter of common observation in the semi-arid and elevated regions of the West that fruit blossoms and other tender vegetation will withstand temperatures that would kill all or nearly all growing vegetation in the lower and more humid districts of the eastern half of the United States. Whether this resistance to cold is due to elevation, humidity, soil, or some unknown factor, or to two or more of these combined, has not been determined, but it seems to be more noticeable when the moisture content of both the soil and the air is low. It has, however, frequently been observed under just the opposite conditions. For example, the apples in the Pecos Valley were, when in full blossom, subjected to a snowstorm lasting 15 hours, during which the temperature was continuously below freezing, and below 30° in portions of the orchard district for several hours. Nevertheless, no noticeable damage was sustained, either to fruit or to young truck crops. This was on April 8, 1919, and the same thing has occurred in previous seasons, having once before (1917) been observed by the writer.

The following data illustrate a remarkable case of resistance to temperatures below freezing after a period of low atmospheric humidity:

Date.	Minimum temperature.	State of apricots.
1919.	°F.	
Mar. 1	31	Buds showing pink.
2	28	
3	27	Blossoms opening.
4	29	
5	19	30 per cent of blossoms open.
6	27	
7	30	50 per cent of blossoms open.
8	29	
9	27	
10	28	
11	18	Trees in full blossom.
12	30	
15	27	Petals falling.
16	34	
18	27	Petals nearly all off.
19	29	
23	....	Fruit swelling.

On March 25 a thorough examination of the trees at different elevations showed less than 7 per cent of the fruit dead or injured; that is, over 93 per cent of the blossoms were developing sound, uninjured fruit. It is not certain that the dead and injured fruit was due to the cold, as normally, under any conditions, a part die and fall off at this stage of development.

It will be noticed that the blossoms were subjected to daily minimum temperatures below freezing during the entire time that the blossoms were opening, with a temperature 14° below freezing when in full blossom.

The temperature records were made by a Weather Bureau minimum thermometer and a thermograph in a cotton region shelter about 80 yards from the nearest trees. During the period under discussion minimum temperatures 1 inch above the surface of the ground averaged 1.4° F. higher, and at an elevation of 24 feet, 0.9° F. higher, than in the shelter.

This substation was in charge of the writer, who personally made the observations tabulated above.

NOTES.

There is some discussion of this subject in Bulletin 89 of the New Mexico Agricultural Experiment Station, 1913–14, by F. Garcia and J. W. Rigney, "Hardiness of fruit buds and flowers to frost." Although other observers have shown that 31° is the danger point for peaches and 28° that for apples, there are differences with different stages of growth, the young fruit being the most tender. While 26.5° to 27° is often detrimental to young fruit, 26° is said to be the critical temperature, though 24° sometimes has little effect. The factors of greatest importance are the degree, duration, and time of day of the greatest cold. When the lowest temperature occurs just before sunrise, the effect is worst.

W. H. Chandler, in an extensive contribution, "The killing of plant tissue by low temperature" (Mo. Agr. Exp. Sta., Research Bull. No. 8, December, 1913, pp. 143–309), gives 22° to 25° or 26° as the killing temperature for young peach flowers, and 29° to 30° as that for older ones and young fruit. This work contains a chart showing maximum and minimum temperatures preceding freezing of fruit buds; also, an extensive bibliography. For a general discussion and bibliography of "Frost and the growing season," by W. G. Reed, see Atlas of American Agriculture, advance sheets 2, Part II, section 1, 1918; also, "A selected [annotated] bibliography of frost in the United States," by W. G. Reed and C. L. Feldkamp, Monthly Weather Review, 1915, 43:512–517.

THE METEOROLOGICAL ACTIVITIES OF THE LATE PROF. EDWARD C. PICKERING.

By ROBERT DE C. WARD.

[Dated: Harvard University, Cambridge, Mass., May, 1919.]

By the death, on February 3, 1919, of Prof. Edward C. Pickering, for more than 40 years director of the Harvard Observatory, meteorology lost an enthusiastic and generous patron. Prof. Pickering would have been the very first to deny that he was in any sense a meteorologist, but he was, throughout his long term of service as professor of astronomy and as head of one of our oldest and best-known observatories, keenly interested in the progress of meteorology and a liberal supporter of meteorological observation and research, even when that research was not directly connected with the work of his observatory. His contributions to meteorology may be briefly summarized under two heads—first, those which were closely related to the astronomical investigations which he undertook or planned; and, second, those which were outside of the field of his own science but to which he gave financial support because he realized their scientific importance.

Under the former head come the regular meteorological observations which for many years formed an important part of the work of the Harvard Observatory. The results of the early observations, from 1840 to 1888, were compiled (by Prof. Arthur Searle) and brought together in one volume of the Annals of the Observatory (vol. 19, pt. 1, 1889). Other early volumes contained the meteorological observations made at Willows, Cal., during the total solar eclipse of January 1, 1889 (by Winslow Upton and A. Lawrence Rotch, vol. 29, pt. 1), and researches on the zodiacal light and a photographic determination of atmospheric absorption (by Arthur Searle and Willamnia P. Fleming, vol. 19, pt. 2). It was, however, in connection with the use of the Boyden fund that Prof. Pickering planned and directed the most important meteorological work of his observatory. In 1887, the Harvard Observatory received a bequest under the will of Mr. Uriah A. Boyden, the income from which was to aid in the establishment of an observatory" at such an elevation as to be free, so far as practicable, from the impediments to accurate observation which occur in the observatories now existing, owing to atmospheric influences." In order to determine the most favorable place for the establishment of the new observatory, it was necessary to make a study of the meteorological conditions at various places which seemed to promise well. Accordingly, preliminary stations, at which astronomical and meteorological work was carried on, were established, in 1888 and 1889, in Colorado and in California. It was in connection with this study of meteorological conditions in Colorado that Prof. Pickering published, in detail, in volume 22 of the Annals (1889) the observations made by the United States Signal Service on the summit of Pikes Peak from 1874 to 1888 (by A. W. Greely). In 1889 an expedition was sent out, under Prof. Solon I. Bailey, to make a study of the meteorological conditions of various places along the west coast of South America. A temporary station was established on Mount Harvard (6,600 feet), about 20 miles northeast of Lima, and full meteorological records were kept from May, 1889, to September, 1890. Later study of the conditions farther south, including cloudiness observations thrice daily from December 14, 1889, to August 23, 1890, at Pampa Central, in the desert of Atacama, led finally to the selection, in October, 1890, of Arequipa, Peru, as the best location for the southern station of the Harvard Observatory. By correspondence carried on in 1887 and 1888, Prof. Pickering had already been able to establish four meteorological stations in Peru, so that observations at Arequipa began in November, 1888, and have continued from that time to now. In connection with the work at Arequipa, a remarkable series of meteorological stations was developed, which extended from the Pacific, at Mollendo, across the Andes to the valley of the Amazon, and included the famous station on El Misti (19,200 feet), "the highest meteorological station in the world." For various reasons, observations at all these stations except Arequipa were suspended at the end of 1900. The volumes on "Peruvian Meteorology" of the Annals (vol. 39, pts. 1 and 2; vol. 49, pt. 2) contain the results of these observations, compiled and discussed by Prof. Solon I. Bailey.

In order to ascertain whether the climatic conditions in South Africa would be better for astronomical work than those at Arequipa, Prof. Pickering sent an expedition to South Africa early in 1909, under Prof. Bailey, who returned in 1910. Meteorological observations were made at several stations, but while the cloudiness is less than at Arequipa or in Cambridge, other conditions proved to be unfavorable, and the project of establishing an observatory in Cape Colony was abandoned.

Prof. Pickering's pole-star recorder is a meteorological instrument whose more extended use would add greatly to our knowledge of the variations of cloudiness at night, concerning which at present relatively little is known.[1]

The second aspect of Prof. Pickering's activities in connection with meteorology concerns his support of investigations which fell outside of the immediate scope of the work of his observatory. One of the objects of the Harvard Observatory, as defined in its statutes, is "cooperation in meteorological investigations." Prof. Pickering lived up to the letter of that statute by cooperating to the fullest extent in the meteorological work of the Blue Hill Observatory and of the New England Meteorological Society.

Blue Hill Observatory was established in 1885 by the late Prof. A. Lawrence Rotch. From that time to the present a close affiliation has existed between Blue Hill and the Harvard Observatory. By a mutually satisfactory financial arrangement between Prof. Pickering and Prof. Rotch, the long and very valuable series of meteorological observations and investigations carried on at Blue Hill have been regularly published in the Annals of the Harvard Observatory. These volumes constitute a notable group of reports which are of the highest credit to American meteorology, and are known all over the world.

The New England Meteorological Society was formed in 1884. Its object was to establish and maintain meteorological stations and to promote popular interest in the study of meteorology. This society had from its start generous support from the United States Signal Service and later from the Weather Bureau. It occupied for eight years in New England the same position as that taken by the then existing State weather services in other parts of the country. In 1892, the society

[1] See MONTHLY WEATHER REVIEW, March, 1919, 47: 154-155.

transferred all its routine work of observation to the Weather Bureau, which then organized a New England weather service, under a director, as in other States, the society, however, maintaining its existence, for the holdings of meetings and the reading of papers, until April, 1896. Beginning with 1888, the work of the New England Meteorological Society was carried on in cooperation with the Harvard Observatory. The observatory published in its Annals a portion of the regular observations taken by the members of the society, as well as the annual summaries, and a considerable series of important investigations carried out by officers and members of the society.[2] By this arrangement the cost of publishing the society's observations and investigations was materially lessened, and the Annals provided a more dignified and more permanent place of publication than could otherwise have been secured. The Harvard Observatory also equipped some of the society's stations.

Even after the transfer of the society's routine observation work to the Weather Bureau, the Harvard Observatory continued for two years to publish the annual report and summary of the New England Weather Service, and also, until the dissolution of the New England Meteorological Society, that organization's investigations were published in the Observatory Annals.

Prof. Pickering's services to meteorology were thus many and valuable, and extended over a long period of years. Few astronomers have contributed as much as he did toward its development. His interest in the progress of all science was keen and enthusiastic, but he had a special interest in meteorology, and never failed to support it when such support could be considered to be within the scope of his own responsibility as director of the Harvard Observatory.

[2] Among these investigations may be mentioned studies of the characteristics of New England climate, types of New England weather, the sea breeze, New England thunderstorms, the Lawrence tornado of 1890, the characteristics of tornadoes, etc.

WALTER GOULD DAVIS.[1]

By Prof. ROBERT DEC. WARD.

The meteorological service of the Argentine Republic will be the enduring monument of Walter Gould Davis, whose death on April 30, at his old homestead in Danville, Vt., removed one of the world's best-known and most highly respected meteorologists.

As a young man Mr. Davis went to Argentina to serve as assistant to Dr. Benjamin Apthorp Gould, who founded the Astronomical Observatory at Cordoba, and, in 1872, established the Argentine Meteorological Service. Dr. Gould continued in charge of this service until toward the end of 1884, when he left Argentina, and in 1885 Mr. Davis succeeded him as director, continuing in that position until his retirement in 1915, after 30 years of active work. Under Mr. Davis's able leadership, the Argentine Meteorological Service attained a position in the very front rank of government meteorological organizations. When he resigned his post, to secure well-deserved rest and to seek to regain his health in his own country, the Argentine service extended over an area of nearly 3,000 miles in a north and south line, its southernmost station being in the South Orkney Islands, in latitude 60° 43′ south. Over 2,000 stations were then cooperating in the work of taking meteorological and magnetic observations. The morning and evening observations from nearly 200 stations were being used in the construction of the daily weather map, in addition to the daily rainfall records from about 1,350 rainfall stations.

Mr. Davis was a tremendously keen, active, and progressive director. He was always well abreast of the times, and often was a pioneer in keeping ahead of the times. An illustration of his desire to have the organization under his control contribute in every possible way to the advancement of meteorological knowledge was his acquirement, in 1904, of the meteorological and magnetic station at Laurie Island, in the South Orkneys, which had originally been established by the Scottish Antarctic Expedition. Since 1904, this remote southern station has been operated, without a break in its records, as a part of the Argentine Meteorological Service. The personnel of this lonely outpost is relieved only once each year, when supplies are sent for the coming 12 months. The men are then completely isolated, without (at last accounts) any mail or cable communication, until the relief vessel returns the following year. Under these conditions of extreme loneliness and hardship, the observers at Laurie Island have maintained their observations for 15 years. This is a remarkable record of scientific work of the greatest importance in the study of world meteorology. In his Laurie Island station Mr. Davis always took great pride, and well he might do so.

Fully alive to all the needs of his service, Mr. Davis called to help him in his scientific work the best meteorologists whom he could find. From this country he secured, among others, Prof. F. H. Bigelow, formerly of the Weather Bureau, who has had charge of the magnetic work in Argentina, and Mr. H. H. Clayton, formerly of Blue Hill Observatory, and now chief of the Department of Forecasts in Buenos Aires.

The high quality of Mr. Davis's work was fully appreciated by his meteorological colleagues everywhere. His reputation as a meteorologist and as the successful administrative head of a large and remarkably efficient organization won for him a position on the International Meteorological Committee, the highest international authority on meteorology. This was a well-deserved recognition of the importance of his contributions to meteorology, and of his sound judgment on scientific matters.

The many publications of the Argentine Meteorological Service which were issued under Mr. Davis's direction constitute an inspiring record of splendid work, well planned, thoroughly organized, and ably carried out.

By the death of Walter Gould Davis the world has lost one of its most eminent meteorologists, and those of his colleagues who had the privilege of knowing him have lost a warm-hearted, sympathetic, and helpful friend.

[1] Reprinted from the Boston Transcript, May 5, 1919.

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C. FITZHUGH TALMAN, Professor in Charge of Library.

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Boletin extraordinario, 31 de diciembre de 1918. Mexico. 1919. 143 p. plates (part. col.) fold. maps. 28 cm. [Describes the organization and history of the Direccion de estudios geograficos y climatologicos, p. 94–108.]

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Moore, John [William].
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Quelques mesures de l'électricité atmosphérique exécutées pendant l'éclipse totale de soleil du 21 août 1914, par Martin Sjöström et Anders Ångström. Stockholm. 1919. 8 p. 2 charts. 2 tables. 29 cm. At head of title: L'éclipse totale de soleil des 20–21 août 1914. 5ième partie. No. 3.

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La théorie électromagnétique du temps. Huitième partie. Communication provisoire. La nouvelle cause des périodes météorologiques et le principe fondamental de l'influence lunaire sur notre atmosphère. Port-au-Prince. 1919. ix, 65 p. fold. chart. fold. tables. 24 cm.

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West, Frank L., & Edlefsen, N. E.
The climate of Utah. Logan, Utah. 1919. 66 p. illus. charts. tables. 23 cm. (Bulletin no. 166. Utah agricultural college. Experiment station.)

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Meteorologische Beobachtungen angestellt in Dorpat im Jahre 1917. 52 Jahrgang. Dorpat. 1919. 111 [1] p. tables. 25 cm.

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

Aeronautics. London. v. 16. 1919.

Lyons, H. G. The supply of meteorological information. p. 412–415. (Apr. 17.) [Deals especially with the requirements of aviation.]

Wimperis, H. A. Air navigation. "The most important of the unsolved problems relating to aviation." p. 482–487. (May 8.) [Includes discussion of winds and fogs.]

Aviation. New York. v. 6. 1919.

Gregg, Willis Ray. Trans-Atlantic flight and meteorology. p. 370–372; 422–425. (May 1 and 19.) [Reprinted from Mo. Weather Rev., Feb., 1919, **47**: 65–75.]

Botanical abstracts. Baltimore. v. 1. December, 1918.

Blodgett, F. H. Weather conditions and crop diseases in Texas. p. 141. [Abstr. Mem. Torrey Bot. Club.]

Engineering news-record. New York. v. 82. April 24, 1919.

Vicente, M. L., & Joslin, C. F. Effect on structures of recent Porto Rico earthquakes. Wood frame proves safest for buildings, with well-built concrete next, but articulated construction is poor. p. 806–808.

Flying. New York. v. 8. May, 1919.

Gregg, Willis Ray. Trans-Atlantic flight from the meteorologist's point of view. p. 357–361. [Reprinted from Mo. Weather Rev., Feb., 1919, **47**: 65–75.

Geographical review. New York. April, 1919.

Richardson, H[erbert] W. The northeastern Minnesota forest fires of October 12, 1918. p. 220–232. [Discusses meteorological features.] [Cf. Mo. Weather Rev., Nov., 1918, **46**: 506–509.]

Taylor, Griffith. Air routes to Australia. p. 256–261. [Includes meteorological data. Published also in Mo. Weather Rev., Feb., 1919, **47**: 78–80.]

National service and international military digest. v. 5. April. 1919.

Günther, H. The seismometer in war service. p. 248. [Abstr.: Schweiz. monatschr. f. Off. aller Waffen.]

Nature. London. v. 105. May 8, 1919.

Chapman, S. The lunar tide in the atmosphere. p. 185–187.

Physico-mathematical society of Japan. Proceedings. Tôkyô. v. 1. April, 1919. p. 88–94.

Nakamura, Saemontarô. Analysis of seismogram. p. 88–94.

Royal meteorological society. Quarterly journal. London. v. 48. April, 1919.

Shaw, Napier. Meteorology: the society and its fellows. p. 95–111.

Richardson, Lewis F. Line squall, France, 6th September, 1917. p. 112.

Chapman, S. The lunar tide in the earth's atmosphere. p. 113–139.

Christy, Miller. The gunfire on the continent during 1918; its audibility at Chignal St. James, near Chelmsford. p. 141–146.

Christy, Miller. Two recent whirlwinds in Essex. p. 147–149.

Brooks, C. E. P. The meteorology of Hebron, Labrador, 1883 to 1912. p. 163–167.

Redway, J. W. Atmospheric pollution. p. 167–169.

Sylvester, Norman L. Rate of travel of depressions over the British Isles during the 12 years 1906–1917. p. 170–171.

Mr. W. B. Tripp. M. Inst. C. E. p. 172. [Obituary.]

Gago, Coutinho. The artificial green flash. [Translated from the Portuguese.] p. 178.

Science. New York. v. 49. May 23, 1919.

Karrer, Enoch, & Tyndall, E. P. T. On the auroral display of May 2, 1919. p. 495–496. [See also *June 6*, p. 542.]

Scientific American. New York. v. 120. May, 1919.

Skerrett, Robert C. Increasing visibility through a knowledge of camouflage. Suggestion of permanent peace-time value drawn from the efforts to make ships invisible. p. 457; 471. (May 3.) [Includes description of a visibility-meter.]

Sterling, Scott, & *others*. The road mirage. p. 485. (May 10.)

Scientific American supplement. New York. v. 87. 1919.

Gregg, Willis Ray. What the weather man thinks of ocean flying. p. 274–275; 300–302. (May 3, 10.) [Reprinted from Mo. Weather Rev., Feb., 1919, **47**: 65–75.]

Symons's meteorological magazine. London. v. 54. April, 1919.

Brown, A. Hampton. Rainfall at Havana and in southwest England. p. 30.

Académie des sciences. Comptes rendus. Paris. Tome 168. 1919.

Guilbert, Gabriel. Sur quelques exemples de "compression de cyclone." p. 691–693. (31 mars.)

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Gautier, Raoul. Nouvelle baisse extraordinaire du baromètre et records de basse pression à Genève. p. 4–7.

Astronomie. Paris. 33 année. Avril, 1919.

Duchesne, H. Sur l'utilisation de l'artillerie à longue portée pour les observations météorologiques. p. 176–177. [Suggests making atmospheric soundings by means of projectiles carrying meteorological apparatus, to be fired from cannon.]

Nature. Paris. 47 année. 1919.

Drosomètre nouveau. p. suppl. 57. (19 avril). [Abstract of paper by Eredia.]

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Dember, H., & Uibe, M. Über die scheinbare Gestalt des Himmelsgewölbes. p. 387–396. (H. 5.)

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Dember, H., & Uibe, M. Über die spektrale Polarisation des diffusen Sonnenlichts in der Erdatmosphäre. p. 208–224. (H. 3.)

Gockel, A[lbert]. Beiträge zur Kenntnis von Farbe und Polarisation des Himmelslichtes. p. 617–638. (H. 8.)

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Hauer, F. v. Die Polarisation des Lichtes in trüben Medien im Hinblicke auf das Himmelslicht. p. 145–160. (H. 2.)

Wegener, Alfred. Elementare Theorie der atmosphärischen Spiegelungen. p. 203–230. (H. 3.)

Annalen der Physik. Beiblätter. Leipzig. Band 42. 1918.

Sverdrup, H. U. Der nordatlantischen Passat. p. 285–286. (H. 13.) [Abstract.]

Visser, S. W. Über die Beugung des Lichtes bei der Bildung von Halos. p. 288. (H. 13.) [Abstract.]

Dember, H., & Uibe, M. Über die scheinbare Gestalt des Himmelsgewölbes. p. 348–349. (H. 16.) [Abstract.]

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Rempp, E. Über einige technische Erfahrungen mit dem Benndorfschen registrierenden Elektrometer und über einige Hilfsapparate. p. 352. (H. 16.) [Abstract.]

Stok, J. P[aulus] van der. Der Zusammenhang zwischen meteorologischen Zuständen in den Niederländen und in umliegenden Orten. I. Luftdruck. p. 443–444. (H. 20/21.) [Abstract.]

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Ångström, Anders. Einigen Beobachtungen über Temperaturwellen. p. 10–13. (Jan.)

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Gockel, A[lbert]. Beiträge zur Kenntnis der in der Atmosphäre vorhandenen durchdringenden Strahlung. p. 15–24. (Jan.)

Schmidt, A[dolf]. Die Erdmagnetische Störung am 17. Juni 1915 in Potsdam und Seddin. p. 25–29. (Jan.)

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Hann, J[ulius] v. Klimatafeln für die Balkanhalbinsel. p. 40–41. (Jan.) [Gives list of climatic tables that have been published in Meteorologische Zeitschrift for stations in the Balkan peninsula.]

Dietzius, Robert. Arbeitshöhe und Schwerepotential. p. 42–44. (Jan.)

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Abbot, C[harles] G[reeley], Fowle, F. E., & Aldrich, L. B. Intensität der Sonnenstrahlung ausserhalb der Atmosphäre. p. 49–55. [Abstract.] (Jan.)

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Wegener, Kurt. Die meteorologischen Aufzeichnungen am Spitzbergen-Observatorium 1912 bis 1913. p. 59–64. (Feb.)

Mazelle, Eduard. Über die Windverhältnisse in den höheren Luftschichten nach den Pilotballonbeobachtungen in Triest. p. 64–69. (Feb.)

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Hann, J[ulius] v. Schlechte Mittel der Bewölkung als Folge eines mangelhaften Beschlusses der Meteorologen-Kongresse. p. 131–133. (März.) [Misleading statistics of cloudiness due to ignoring density of clouds.]

C. Kassner: Über die Zunahme des Nebels in Sofia und ihre Ursachen. p. 135–138. (März.) [Increased fog in Sofia due to increase of smoke.]

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Gockel, A[lbert]. Zur Gewitterprognose. p. 544–545. (Dez.) [Enhanced conductivity of the atmosphere as a prognostic of thunderstorms.]

Barkow, E. Über eine ungewöhnliche Haloerscheinung. p. 545–546. (Dez.)

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SPECIAL OBSERVATIONS.

HALO PHENOMENA OBSERVED DURING APRIL, 1919.

By WILLIS RAY GREGG, Meteorologist.

Station.	Altitude.	Latitude.	Longitude.	Date.	Form observed.	Time of— Beginning.	Time of— Ending.	Theodolite readings. Time.	Radius inside.	Radius outside.	Length of arc.	Distance from sun or moon.	Altitude of sun or moon.
	m	° ′	° ′						°	°	°	°	°
Broken Arrow, Okla.*	233	36 02	95 49	4	Solar halo, 22°	10:00 a. m.	3:30 p. m.						
				11	Solar halo, 22°	9:45 a. m.	10:50 a. m.	9:45 a. m.	22	23	300		45.5
				18	Solar halo, 22°	9:12 a. m.	9:40 a. m.	9:15 a. m.			30		41.3
				18	Parhelion, 22°, right	9:28 a. m.	9:40 a. m.						
				18	Parhelion, 22°, left.	9:12 a. m.	9:40 a. m.						
				21	Solar halo, 22°	8:20 a. m.	8:45 a. m.						
				23	Solar halo, 22°	8:32 a. m.	8:45 a. m.	8:36 a. m.	20.8	222	15		35
				23	Parhelion, 22°, left.	8:20 a. m.	8:27 a. m.	8:23 a. m.		22			
				23	Solar halo, 22°	11:10 a. m.	11:30 a. m.				15		
				29	Solar halo, 22°	10:18 a. m.	10:35 a. m.						
Cincinnati, Ohio	191	39 06	84 30	6	Solar haol, 22°	11:48 a. m.	12:15 p. m.						
				6	Parhelion, 22°, right	5:05 p. m.	5:20 p. m.						
				7	Lunar halo, 22°	7:30 p. m.	8:20 p. m.						
				8	Lunar halo, 22°	8:00 p. m.	8:40 p. m.						
				9	Solar haol, 22°	11:40 a. m.	1:30 p. m.						
				13	Lunar halo, 22°	8:00 p. m.	8:30 p. m.						
				18	Solar halo, 22°	5:00 p. m.	5:50 p. m.						
				18	Parhelion, 22°, left.	5:10 p. m.	5:12 p. m.						
				27	Solar halo, 22°	10:55 a. m.	12:30 p. m.						
				29	Solar halo, 22°	11:15 a. m.	11:58 a. m.						
Dayton, Ohio	274	39 46	84 10	6	Solar halo, 22°	1:00 p. m.	1:30 p. m.						
				7	Lunar halo, 22°	7:30 p. m.	D. N.						
				8	Lunar halo, 22°	7:45 p. m.	D. N.						
				13	Lunar halo, 22°	8:50 p. m.	9:15 p. m.						
				18	Solar halo, 22°	11:35 a. m.	11:50 a. m.						
				19	Solar halo, 22°	3:25 p. m.	3:40 p. m.						
				27	Solar halo, 22°	11:15 a. m.	3:10 p. m.						
				29	Solar halo, 22°	9:45 a. m.	12:30 p. m.						
Drexel, Nebr.*	396	41 20	96 16	5	Solar halo, 22°	9:50 a. m.	10:10 a. m.	9:58 a. m.	21	22	15		39
				6	Parhelion, 22°, right	7:30 a. m.	8:14 a. m.	7:49 a. m.			3	25	18
				6	Parhelion, 22°, left.	7:30 a. m.	8:14 a. m.	7:49 a. m.			4	25	18
Ellendale, N. Dak.*	444	45 59	98 34	4	Solar halo, 22°	12:15 p. m.	12:56 p. m.	12:35 p. m.	22	225	360		50
				11	Solar halo, 22°	6:05 p. m.	6:45 p. m.	6:10 p. m.			90		
				11	Lunar halo, 22°			9:30 p. m.			360		
				15	Solar halo, 22°	7:55 a. m.	6:55 p. m.	8:10 a. m.	22.5	24	210		24
				15	Solar halo, 46°	8:20 a. m.	8:28 a. m.	8:25 a. m.	45		120		25
				20	Parhelion, 22°, right	6:35 a. m.	6:50 a. m.				3		
				22	Solar halo, 22°	11:20 a. m.	11:42 a. m.	11:35 a. m.	22.5	23.5	360		54.5
Groesbeck, Tex.*	141	31 30	96 28	2	Solar halo, 22°	12:57 p. m.	1:45 p. m.	1:24 p. m.	20.5	22.5	360		63
				23	Solar halo, 22°	2:25 p. m.	2:35 p. m.	2:30 p. m.	22	24	30		55.5
				24	Solar halo, 22°	8:25 a. m.	2:35 p. m.	8:30 a. m.	22	23.5	260		33.5
Leesburg, Ga.*	85	31 47	84 14	3	Solar halo, 22°	9:24 a. m.		10:00 a. m.	22		120		
				6	Solar halo, 22°	11:45 a. m.		12:15 p. m.	22		360		
				6	Lunar halo, 22°	6:30 p. m.	D. N.	7:05 p. m.	22		360		
				8	Lunar halo, 22°	6:20 p. m.	D. N.	6:40 p. m.	22		360		
				9	Solar halo, 22°	8:12 a. m.	4:45 p. m.	9:07 a. m.	22		360		39
				9	Lunar halo, 22°	6:20 p. m.	D. N., P.	6:40 p. m.	22		360		
				10	Parhelion, 22°, left.	6:40 a. m.	6:45 a. m.	6:40 a. m.				23	20
				10	Solar halo, 22°	6:34 a. m.	10:50 a. m.	6:45 a. m.	22		190		20
				11	Solar halo, 22°	2:02 p. m.	2:12 p. m.	2:05 p. m.	22		60		48
				12	Lunar halo, 22°	9:10 p. m.	9:50 p. m.	9:30 p. m.	22		190		
				15	Solar halo, 22°	2:01 p. m.	4:35 p. m.	2:50 p. m.	22		190		39.5
				16	Solar halo, 22°	1:15 p. m.	3:15 p. m.	1:20 p. m.	22		100		59.5
				24	Parhelion, 22°, right	6:40 a. m.	6:48 a. m.	6:42 a. m.					21.5
				24	Solar halo, 22°	7:14 a. m.	12:30 p. m.	11:37 a. m.	22		180		
				25	Solar halo, 22°	5:40 a. m.	10:00 a. m.	6:50 a. m.	22		300		23
				25	Parhelion, 22°, left.	5:55 a. m.	6:15 a. m.	6:10 a. m.					
				25	Upper tangent arc.	5:50 a. m.	7:05 a. m.	6:10 a. m.			10		
				26	Solar halo, 22°	9:25 a. m.	9:35 a. m.	9:25 a. m.	22		30		
				27	Solar halo, 22°	6:20 a. m.	10:15 a. m.	6:50 a. m.	22		300		22
				27	Solar halo, 46°	12:30 p. m.	1:05 p. m.	12:40 p. m.	46		45		
				29	Solar halo, 22°	10:25 a. m.	5:15 p. m.	2:30 p. m.	22		320		
				30	Solar halo, 22°	6:45 a. m.	1:50 p. m.	7:05 p. m.	22		290		25
Madison, Wis.	297	43 05	89 23	1	Parhelion, 22°, right	5:00 p. m.	5:30 p. m.						
				2	Solar halo, 22°	10:00 a. m.	12:00 m.						
				5	Solar halo, 22°	10:50 a. m.	11:20 a. m.						
				5	Upper tangent arc.	10:50 a. m.	11:20 a. m.						
				5	Lower tangent arc.	10:50 a. m.	11:20 a. m.						
				6	Solar halo, 22°	9:30 a. m.	1:30 p. m.						
				8	Solar halo, 22°	11:55 a. m.	1:00 p. m.						
				8	Solar halo, 22°	3:25 p. m.	4:00 p. m.						
				8	Parhelion, 22°, right	3:25 p. m.	5:46 p. m.						
				8	Parhelion, 22°, left.	3:25 p. m.	5:43 p. m.						
				8	Upper tangent arc.	3:25 p. m.	4:00 p. m.						
				8	Lunar halo, 22°	7:30 p. m.	D. N., P.						
				17	Solar halo, 22°	5:15 p. m.	6:10 p. m.						
				17	Parhelion, 22°, right	5:20 p. m.	5:25 p. m.						
				18	Solar halo, 22°	10:00 a. m.	1:30 p. m.						
				18	Parhelion, 22°, right	5:35 p. m.	6:10 p. m.						
				18	Parhelion, 22°, left.	5:40 p. m.	6:10 p. m.						
				19	Solar halo, 22°	6:55 a. m.	3:00 p. m.						
				20	Solar halo, 22°	8:45 a. m.	12:15 p. m.						
				20	Parhelion, 22°, right	10:30 a. m.	10:50 a. m.						
				20	Parhelic circle	10:30 a. m.	10:50 a. m.						
				21	Solar halo, 22°	7:35 a. m.	9:30 a. m.						
				21	Solar halo, 22°	2:00 p. m.	5:15 p. m.						
				21	Parhelion, 22°, right	7:35 a. m.	8:10 a. m.						
				21	Parhelion, 22°, left.	7:35 a. m.	8:10 a. m.						
				21	Parhelic circle	7:35 a. m.	8:10 a. m.						
				22	Solar halo, 22°	4:15 p. m.	5:35 p. m.						
				22	Parhelion, 22°, right	4:45 p. m.	5:35 p. m.						
				22	Parhelion, 22°, left.	4:45 p. m.	5:35 p. m.						
				26	Solar halo, 22°	5:15 p. m.	5:35 p. m.						
				26	Parhelion, 22°, right	5:15 p. m.	5:30 p. m.						
				29	Solar halo, 22°	11:05 a. m.	3:10 p. m.						
Nashville, Tenn	166	36 10	86 47	3	Solar halo, 22°	2:30 p. m.	2:50 p. m.	2:45 p. m.					
				9	Solar halo, 22°	10:15 a. m.	10:30 a. m.	10:15 a. m.					
				12	Parhelion, 22°, right	5:50 p. m.	5:52 p. m.	5:50 p. m.					
				12	Parhelion, 22°, left.	5:40 p. m.	5:55 p. m.	5:50 p. m.					

* Aerological station.

Halo phenomena observed during April, 1919—Continued.

Station.	Altitude.	Latitude.	Longitude.	Date.	Form observed.	Time of— Beginning.	Time of— Ending.	Theodolite readings. Time.	Radius inside.	Radius outside.	Length of arc.	Distance from sun or moon.	Altitude of sun or moon.
	m	° ′	° ′						°	°	°	°	°
Nashville, Tenn. (continued)				23	Solar halo, 22°	11:40 a. m.	12:00 m.	11:45 a. m.					
				24	Solar halo, 22°	5:20 p. m.	5:45 p. m.	5:30 p. m.					
				24	Parhelion, 22°, right	5:20 p. m.	5:45 p. m.	5:30 p. m.					
				27	Solar halo, 22°	7:00 a. m.	11:00 a. m.	9:15 a. m.					
Royal Center, Ind.*	225	40 53	86 29	2	Solar halo, 22°	7:10 a. m.	7:30 a. m.				180		
				2	Parhelion, 22°, right	7:05 a. m.	7:40 a. m.						
				2	Parhelion, 22°, left	7:05 a. m.	7:40 a. m.						
				2	Solar halo, 22°	10:25 a. m.	5:30 p. m.	11:46 a. m.	22	23.4	360	22	54
				5	Solar halo, 22°	9:08 a. m.	1:30 p. m.				360	22	
				8	Solar halo, 22°	7:20 a. m.	7:50 a. m.				150	22	
				8	Solar halo, 22°	2:00 p. m.	5:30 p. m.				360	22	
				18	Solar halo, 22°	7:30 a. m.	10:30 a. m.	8:00 a. m.			360	22	
				18	Solar halo, 22°	1:15 p. m.	5:10 p. m.	2:00 a. m.			360	22	
				19	Solar halo, 22°	12:30 p. m.	3:10 p. m.	1:00 p. m.			270	22	
				29	Solar halo, 22°	6:45 a. m.	11:15 a. m.	9:50 a. m.	21.7	23.2	360		53.2
Tatoosh Island, Wash	26	48 23	124 44	1	Solar halo, 22°	9:55 a. m.	11:30 a. m.						
				1	Parhelion, 22°, right	9:55 a. m.	11:30 a. m.						
				1	Parhelion, 22°, left	9:55 a. m.	11:30 a. m.						
				1	Upper tangent arc	10:00 a. m.	10:20 a. m.						
				1	Parhelic circle	10:15 a. m.	10:20 a. m.						
				1	Solar halo, 22°	11:50 a. m.	6:05 p. m.						
				1	Parhelion, 22°, right	12:45 p. m.	4:47 p. m.						
				1	Parbelion, 22°, left	12:50 p. m.	4:47 p. m.						
				1	Upper tangent arc	12:45 p. m.	4:47 p. m.						
				1	Lower tangent arc	12:06 p. m.	3:11 p. m.						
				1	Solar halo, 46°	12:45 p. m.	2:22 p. m.						
				1	Solar halo, 46°	4:12 p. m.	4:15 p. m.						
				1	Parhelion, 46°, right	3:35 p. m.	3:43 p. m.						
				1	Parhelion, 46°, left	3:42 p. m.	3:43 p. m.						
				1	Circumzenithal arc	4:12 p. m.	4:15 p. m.						
				1	Parhelic circle	12:48 p. m.	2:22 p. m.						
				1	Paranthelion, 120°, right.	12:55 p. m.	2:54 p. m.						
				1	Paranthelion, 120°, left.	1:08 p. m.	2:36 p. m.						
				2	Solar halo, 22°	8:36 a. m.	9:40 a. m.						
				3	Solar halo, 22°	8:14 a. m.	9:10 a. m.						
				4	Solar halo, 22°	1:54 p. m.	2:00 p. m.						
				4	Upper tangent arc	1:55 p. m.	1:57 p. m.						
				5	Solar halo, 22°	7:05 a. m.	6:35 p. m.						
				5	Parhelion, 22°, right	6:12 p. m.	6:17 p. m.						
				5	Parhelion, 22°, left	3:02 p. m.	3:10 p. m.						
				5	Upper tangent arc	3:02 p. m.	3:08 p. m.						
				6	Solar halo, 22°	4:29 p. m.	5:38 p. m.						
				6	Parhelion, 22°, right	4:49 p. m.	5:38 p. m.						
				8	Parhelion, 22°, right	6:25 a. m.	6:58 a. m.						
				8	Parhelion, 22°, left	6:26 a. m.	6:30 a. m.						
				10	Solar halo, 22°	12:08 p. m.	12:15 p. m.						
				11	Solar halo, 22°	10:48 a. m.	1:40 p. m.						
				11	Parhelion, 22°, right	7:59 a. m.	8:10 a. m.						
				11	Parhelion, 22°, left	7:59 a. m.	8:10 a. m.						
				12	Parhelion, 22°, left	6:10 p. m.	6:35 p. m.						
				13	Solar halo, 22°	6:03 a. m.	8:30 a. m.						
				13	Parhelion, 22°, right	6:45 a. m.	8:30 a. m.						
				13	Parhelion, 22°, left	6:45 a. m.	8:30 a. m.						
				14	Light pillar	4:40 a. m.	4:54 a. m.						
				14	Parhelion, 22°, right	6:24 a. m.	6:32 a. m.						
				14	Solar halo, 22°	11:10 a. m.	7:07 p. m.						
				15	Solar halo, 22°	D. N. a	4:38 a. m.						
				15	Light pillar	4:38 a. m.	4:45 a. m.						
				15	Solar halo, 22°	6:50 a. m.	11:15 a. m.						
				15	Parhelion, 22°, right	11:08 a. m.	11:15 a. m.						
				15	Parhelion, 22°, left	10:22 a. m.	11:15 a. m.						
				15	Upper tangent arc	9:35 a. m.	11:15 a. m.						
				15	Parhelic circle	9:57 a. m.	11:15 a. m.						
				15	Solar halo, 22°	4:45 p. m.	6:40 p. m.						
				15	Parhelion, 22°, right	6:10 p. m.	6:20 p. m.						
				17	Solar halo, 22°	7:55 a. m.	7:57 a. m.						
				17	Solar halo, 22°	1:06 p. m.	2:00 p. m.						
				18	Lunar halo, 22°	4:03 a. m.	4:20 a. m.						
				18	Solar halo, 22°	7:24 a. m.	8:55 a. m.						
				18	Solar halo, 22°	11:43 a. m.	6:20 p. m.						
				18	Parhelion, 22°, right	2:06 p. m.	3:05 p. m.						
				18	Parhelion, 22°, left	2:21 p. m.	3:05 p. m.						
				18	Circumscribed halo	11:49 a. m.	3:05 p. m.						
				18	Solar halo, 46°	1:40 p. m.	1:50 p. m.						
				19	Solar halo, 22°	4:41 p. m.	4:58 p. m.						
				19	Parhelion, 22°, right	4:41 p. m.	4:44 p. m.						
				21	Solar halo, 22°	2:40 p. m.	7:00 p. m.						
				21	Parhelion, 22°, right	2:40 p. m.	5:57 p. m.						
				21	Parhelion, 22°, left	4:20 p. m.	5:00 p. m.						
				21	Upper tangent arc	4:50 p. m.	5:50 p. m.						
				22	Solar halo, 22°	6:20 a. m.	3:50 p. m.						
				22	Parhelion, 22°, right	6:20 a. m.	6:39 a. m.						
				23	Solar halo, 22°	1:30 p. m.	4:50 p. m.						
				26	Solar halo, 22°	4:10 p. m.	4:57 p. m.						
				29	Solar halo, 22°	12:55 p. m.	7:25 p. m.						
				29	Parhelion, 22°, right	4:15 p. m.	7:25 p. m.						
				29	Parhelion, 22°, left	4:15 p. m.	7:10 p. m.						
				29	Upper tangent arc	2:40 p. m.	4:20 p. m.						
				29	Solar halo, 46°	4:45 p. m.	4:57 p. m.						
				29	Circumzenithal arc	4:45 p. m.	4:57 p. m.						
				29	Light pillar	6:54 p. m.	7:20 p. m.						
				30	Paraselene, 22°, right.	5:25 a. m.	5:30 a. m.						
York, N. Y	232	42 52	77 53	3	Solar halo, 22°	9:50 a. m.	11:10 a. m.	10:00 a. m.			190		43.5
				3	Parhelion, 22°, right	9:50 a. m.	10:15 a. m.	10:00 a. m.				23.5	
				5	Solar halo, 22°	7:00 p. m.	7:20 p. m.	7:00 p. m.			75		4
				6	Solar halo, 22°	9:30 a. m.	11:00 a. m.	9:30 a. m.			100		31
				14	Solar halo, 22°	1:53 p. m.	5:40 p. m.	2:00 p. m.			360		54
				19	Solar halo, 22°	6:00 p. m.	7:15 p. m.	6:20 p. m.			200		
				19	Parhelion, 22°, left	6:10 p. m.	7:15 p. m.						
				22	Solar halo, 22°	3:50 p. m.	5:00 p. m.						
				23	Solar halo, 22°			2:— p. m.			360		

* Aerological station.

Halo phenomena observed during April, 1919—Continued.

Station.	Date.	Colors.†	Degree of brightness.	Clouds.			Station pressure.	Precipitation.	
				Amount.	Kind.	Direction.		Last previous ended.	First subsequent began.
Broken Arrow, Okla.*	4	R	Dim	6	Ci.	w.	Stationary	9:45 a. m., 3d	D. N., a., 7th.
	11	Y	Dim	7	Ci. St.	w.	Stationary	7:15 a. m., 9th	5:55 p. m., 14th.
	18	R. O. Y	Bright	7	Ci. St.	nw.	Rising	6:15 p. m., 14th	D. N., a., 25th.
	18								
	18								
	21	Y	Dim	6	Ci. St.	w.	Stationary	6:15 p. m., 14th	D. N., a., 25th.
	23	R. Y	Bright	8 Few	Ci. St. Ci. Cu.	wnw. wnw.	Rising	6:15 p. m., 14th	D. N., a., 25th.
	23		Bright	8 Few	Ci. St. Ci. Cu.	wnw. wnw.			
	23	R. O. Y	Bright	3	Ci. St.	wnw.	Rising	6:15 p. m., 14th	D. N., a., 25th
	29	R	Dim	Few	Ci. St.	w.	Stationary	7:30 p. m., 28th	6:12 p.m., 4th.
Cincinnati, Ohio	6	R	Dim	3	Ci. St.	w.	Falling	D. N., a., 4th	5:29 a. m., 8th.
	6	R	Dim	3	Ci. St.	w.			
	7		Dim	5	Ci. St.	sw.	Rising	D. N., a., 4th	5:29 a. m., 8th.
	8		Dim	7	Ci. St.	w.	Stationary	8:20 a. m., 8th	1:55 a. m., 10th.
	9	R	Dim	9 Few	Ci. St. Cu.	w. sw.	Falling	8:20 a. m., 8th	1:55 a. m., 10th.
	13	R	Brilliant	8	Ci. St.	nw.	Stationary	3:32 p. m., 10th	D. N., p., 13th.
	18		Dim	6 1	Ci. St. St. Cu.	nw. nw.	Stationary	7:35 p. m., 17th	4:30 p. m., 20th
	18		Dim						
	27	R. O. Y. G. B.	Dim	3 3	Ci. St. A. St.	w. w.	Falling	4:45 p. m., 23d	5:47 p. m., 27th.
	29	R. O. Y. G. B.	Brilliant	4 2	Ci. St. A. St.	w. w.	Falling	D. N., P., 28th	
Dayton, Ohio	6		Dim	7	Ci. St.	sw.	Falling	5:55 p. m., 4th	4:12 a. m., 9th.
	7		Dim	7	Ci. St.	sw.	Rising	5:55 p. m., 4th	4:12 a. m., 9th.
	8		Dim	8	Ci. St.	w.	Stationary	5:55 p. m., 4th	4:12 a. m., 9th.
	13		Dim	8	Ci. St.	w.	Stationary	4:21 p. m., 10th	D. N., a., 14th.
	18	R. O. B	Bright	4	Ci. St.	nw.	Stationary	6:30 p. m., 17th	3:06 p. m., 20th
	19	R	Dim	5	Ci. St.	nw.	Falling	6:30 p. m., 17th	3:06 p. m., 20th.
	27	R. O. B	Bright	8	Ci. St.	nw.	Falling	4:18 p. m., 23d	5:28 p. m., 27th.
	29	R	Dim	9	Ci. St.	nw.	Falling	6:30 p. m., 28th	9:05 p. m., 29th.
Drexel, Nebr.*	5	W	Bright	10	Ci. St.	sw.	Rising	6:08 p. m., 2d	6:40 p. m., 6th.
	6	O. Y. G. B. I. V. W.	Dim	6 2	Ci. St. A. Cu.	wsw. wsw.	Falling	D. N., a., 2d	12: 5 p. m., 6th.
	6	O. Y. G. B. I. V. W.	Dim						
Ellendale, N. Dak.*	4	R	Bright	2	Ci. St.	w.	Falling	8:35 p. m., 2d	10:05 a. m., 6th.
	11	O. G. B	Dim	1 4	Ci. St. A. Cu.	sw. sw.	Rising	7:40 p. m., 8th	10:40 a. m., 14th.
	11	B	Dim	4	Ci. St.	sw.			
	15	R. O. G. B	Bright	10	A. St.	nne.	Falling	5:35 a. m., 15th	7:05 a. m., 19th.
	15	Y. G	Dim	10	A. St.	nne.			
	20	R. O. G. B	Bright	6 1	Ci. St. A. Cu.	w. w.	Rising	9:15 a. m., 19th	D. N., a., 21st.
	22	Y. G. B	Dim	10	Ci. St.	w.	Stationary	8:16 a. m., 21st	8:50 p. m., 22d.
Groesbeck, Tex.*	2	Y. G. B	Dim	9	Ci. St.	w.	Falling	1:00 p. m., 30th	3:35 p. m., 2d.
	23	R. O. Y. G	Bright	5 1	Ci. St. St. Cu.	w. sw.	Falling	7:47 a. m., 15th	D. N., a., 26th.
	24	R. O. Y. G	Bright	4 3	Ci. St. St. Cu.	w. sw.	Rising	7:47 a. m., 15th	D. N., a., 26th.
Leesburg, Ga.*	3	R	Dim	1 6	Ci. Ci. St.	w. w.	Falling	D. N., a., 27th	10:38 a. m., 4th.
	6	R. O. Y	Bright	2 5	Ci. Ci. St.	w. w.	Falling	10:40 a. m., 4th	Noon, 7th.
	6			1 3	Ci. St. A. Cu.	w. sw.	Stationary	10:40 a. m., 4th	Noon, 7th.
	8			8	Ci. St.	w.	Stationary	2:00 p. m., 7th	2:45 p. m., 10th.
	9	R. Y	Dim	2 8	Ci. St. A. St.	w. ssw.	Rising	2:00 p. m., 7th	2:45 p. m., 10th.
	9	R	Dim	10	A. St.	w.	Stationary	2:00 p. m., 7th	2:45 p. m., 10th.
	10	R. Y	Bright	9	Ci. St.	w.	Stationary	2:00 p. m., 7th	2:45 p. m., 10th.
	10	R	Dim	9	Ci. St.	w.	Stationary	2:00 p. m., 7th	2:45 p. m., 10th.
	11	R. Y	Dim	3 1	Ci. A. St.	ssw. w.	Stationary	D. N., a., 11th	9:33 p. m., 15th.
	12	R. Y	Dim	1	Ci.	wsw.	Stationary	8:40 a. m., 11th	9:33 p. m., 15th.
	15	R. Y. G	Dim	1 Few.	Ci. Ci. Cu.	wnw. w.	Stationary	8:40 a. m., 11th	9:33 p. m., 15th.
	16	R. O. Y. G	Bright	3 7	Ci. St. Cu.	w. wnw.	Stationary	10:30 a. m., 16th	7:10 a. m., 26th.
	24	R. Y	Dim	7	Ci. St.	nw.	Stationary	10:38 a. m., 16th	7:10 a. m., 26th.
	24	R. Y	Dim	1 3	Ci. Ci. St.	nw. nw.	Falling	10:38 a. m., 16th	7:10 a. m., 26th.
	25	R. O. Y	Bright	2 7	Ci. Ci. St.	w. w.	Stationary	10:38 a. m., 16th	7:10 a. m., 26th.
	25	R. Y	Bright						
	25	R. Y	Bright						
	26	R. Y. G	Bright	2 3	A. St. A. Cu.	wnw. wnw.	Stationary	8:10 a. m., 26th	5:50 p. m., 29th.
	27	R. Y	Dim	10	Ci. St.	nw.	Stationary	8:10 a. m., 26th	5:50 p. m., 29th.
	27	R. Y. G	Bright	3 1	A. St. A. Cu.	w. sw.	Falling	8:10 a. m., 26th	5:50 p. m., 29th.
	29	R. O. Y	Dim	7 Few.	Ci. St. A. Cu.	w. w.	Falling	8:10 a. m., 26th	5:50 p. m., 29th.
	30	R. Y	Dim	4 1	Ci. St. Ci. Cu.	w. w.	Stationary	6:34 p. m., 29th	12:20 p. m., 30th.
Madison, Wis.	1	W	Dim	3	Ci. St.	w.	Falling	6:38 a. m., 31st.	2:58 p. m., 2d.
	2	W	Dim	10	Ci. St.	w.	Falling	6:38 a. m., 31st	2:58 p. m., 2d.
	5	R	Brilliant	Few. 9	Ci. St. A. St.	w. sw.	Falling	9:00 a. m., 5th	5:10 p. m., 5th.
	5	R	Brilliant						
	5	R	Brilliant						
	6	R	Brilliant	10	Ci. St.	w.	Stationary	6:40 p. m., 5th	D. N., a., 7th.
	8		Brilliant	10	Ci. St.	w.	Rising	D. N., p., 7th	D. N., a., 9th.
	8								
	8	R. B	Brilliant	7 2	Ci. St. Ci. Cu.	w. w.			
	8	R. B	Brilliant	7 2	Ci. St. Ci. Cu.	w. w.			

* Aerological station.

† Beginning with part nearest sun or moon. R, red: O, orange, etc.

Halo phenomena observed during April, 1919—Continued.

Station.	Date.	Colors.†	Degree of brightness.	Clouds. Amount.	Clouds. Kind.	Clouds. Direction.	Station pressure.	Precipitation. Last previous ended.	Precipitation. First subsequent began.
Madison, Wis. (continued)	8								
	8	W	Bright	8	Ci. St.	w.	Rising	D. N., p., 7th	D. N., a., 9th.
	17	R. B	Bright	4 2	Ci. St. St. Cu.	sw. nw.	Rising	D. N., a., 17th	8:40 p. m., 19th.
	17		Dim	4 2	Ci. St. St. Cu.	sw. nw.			
	18	R	Brilliant	10	Ci. St.	w.	Falling	D. N., a., 17th	8:40 p. m., 19th.
	18		Bright	3	Ci. St.	w.			
	18		Bright	3	Ci. St.	w.			
	19	R	Bright	10	Ci. St.	sw.	Falling	D. N., a., 17th	8:40 p. m., 19th.
	20	R	Bright	3	Ci. St.	w.	Rising	D. N., a., 20th	5:45 a. m., 23d.
	20	W	Faint						
	20	W	Faint						
	21		Bright	7	Ci. St.	w.	Falling	D. N., a., 20th	5:45 a. m., 23d.
	21								
	21		Bright	7	Ci. St.	w.			
	21		Bright	7	Ci. St.	w.			
	21								
	22		Bright	2 5	Ci. Ci. St.	w. w.	Stationary	D. N., a., 20th	5:45 a. m., 23d.
	22		Brilliant	2 5	Ci. Ci. St.	w. w.			
	22		Bright	2 5	Ci. Ci. St.	w. w.			
	26	R	Bright	5	Ci. St.	w.	Falling	8:15 a. m., 24th	5:40 a. m., 27th.
	26		Bright						
	29	R	Bright	4 6	Ci. St. St. Cu.	w. s.	Falling	D. N., p., 27th	6:20 a. m., 30th.
Nashville, Tenn	3	R. O	Dim	4 3	Ci. St. A. Cu.	w. w.	Falling	8:00 p. m., 30th	D. N., a., 4th.
	9		Dim	8	Ci. St.	sw.	Falling	8:15 a. m., 7th	3:30 p. m., 9th.
	12	R	Dim	Few. 4	Ci. St. A. St.	w. w.	Rising	12:20 p. m., 10th	9:00 p. m., 12th.
	12	R. Y. G	Bright	Few. 4	Ci. St. A. St.	w. w.			
	23		Dim	3 Few.	A. St. A. Cu.		Falling	4:00 p. m., 16th	7:20 p. m., 23d.
	24	R. O. Y. G	Bright	5 2	Ci. St. A. St.	nw. nw.	Rising	D. N., p., 23d	8:00 a. m., 25th.
	24								
	27	R. O	Bright	10	Ci. St.	w.	Stationary	10:30 a. m., 25th	1:45 p. m., 27th.
Royal Center, Ind *	2	R	Dim	6	Ci. St.	nw.	Falling	D. N., a., 30th	12:03 a. m., 3d.
	2		Dim	6	Ci. St.	nw.			
	2		Dim	6	Ci. St.	nw.			
	2	R. O. Y. G. B.	Bright	9	Ci. St.	nw.	Falling	D. N., a., 30th	12:03 a. m., 3d.
	5	R	Dim	10	Ci. St.	w.	Falling	4:30 p. m., 3d	11:40 p. m., 7th.
	8	R	Dim	5	A. St.	sw.	Rising	D. N., a., 8th	4:15 a. m., 9th.
	8	R	Dim	6	Ci. St.	sw.	Stationary		
	18	R	Dim	4	Ci. St.	nw.	Rising	4:00 p. m., 17th	10:20 a. m., 20th.
	18	R	Dim	3	Ci. St.	nw.	Falling		
	19	R	Dim	8	Ci. St.	nw.	Falling	4:00 p. m., 17th	10:20 a. m. 20th.
	29	R. O. Y. G. B.	Bright	5	Ci. St.	w.	Stationary	11:05 a. m., 28th	D. N., p., 29th.
Tatoosh Island, Wash	1	O. V	Bright	8	Ci. St.	w.	Rising	D. N., p., 30th	11:50 a. m., 3d.
	1	R. Y. B	Bright						
	1	R. Y. B	Bright						
	1	W	Dim	8	Ci. St.	w.			
	1	W	Dim	8	Ci. St.	w.			
	1	R.O.Y.G.B.V.	Brilliant	6	Ci. St.	w.	Falling	D. N., P., 30th	11:50 a. m., 3d.
	1	R. Y. B	Bright	6	Ci. St.	w.			
	1	R. Y. B	Bright	6	Ci. St.	w.			
	1	R. Y. B	Bright	6	Ci. St.	w.			
	1	R. B	Dim	6	Ci. St.	w.			
	1	R. B	Dim	6	Ci. St.	w.			
	1								
	1	W	Dim	8 Few.	Ci. St. Cu.	w.			
	1	W	Dim	8 Few.	Ci. St. Cu.	w.			
	1	R	Dim	5 Few.	Ci. Cu.	w.			
	1	W	Bright	6	Ci. St.	w.			
	1	W	Bright	6	Ci. St.	w.			
	1	W	Bright	6	Ci. St.	w.			
	2	O	Dim	8	A. St.	w.	Rising	D. N., P., 30th	11:50 a. m., 3d.
	3	W	Dim	3 4	Ci. A. St	w. s.	Falling	D. N., P., 30th	11:50 a. m., 3d.
	4	O	Dim	2 2	Ci. St. Cu.	w. sw.	Rising	1:20 p. m., 4th	2:22 p. m., 4th.
	4	O	Dim						
	5	O. V	Dim	7 3	A. St. Cu.	sw. ne.	Falling	5:10 a. m., 5th	1:42 p. m., 5th.
	5	R. Y. B	Dim	9	A. St.		Rising	1:51 p. m., 5th	D. N., a., 7th.
	5	R.O.Y.G.B.V.	Bright	1 3	Ci. St. A. St.	nw. nw.			
	5	O	Dim						
	6	W	Dim	4 4	Ci. St. Cu.	nw. w.	Rising	1:51 p. m., 5th	D. N., a., 7th.
	6	R. Y. B	Dim						
	8	R. Y. B	Brilliant	2	Ci. St.	w.	Falling	5:20 a. m., 7th	D. N., a., 9th.
	8	R. Y. B	Bright						
	10	O	Dim	Few. 5	A. St. Cu.	w. w.	Rising	12:05 p. m., 10th.	4:29 p. m., 10th.
	11			1 8	Ci. St. Cu.	ssw. s.	Rising	10:48 a. m., 11th	4:15 p. m., 11th.
	11	R. B	Dim	1 Few.	Ci. St. Cu.	s. w.		D. N., a., 11th	10:28 a. m., 11th.
	11	R. B	Dim						
	12	R.O.Y.G.B.V.	Bright	1 1	A. St. Cu.	w. w.	Falling	11:45 a. m., 12th.	D. N., a., 14th.
	13	O	Dim	3	A. St.	s.	Rising	11:45 a. m., 12th.	D. N., a., 14th.

* Aerological station.

† Beginning with part nearest sun or moon. R, red; O, orange, etc.

Halo phenomena observed during April, 1919—Continued.

Station.	Date.	Colors.†	Degree of brightness.	Clouds. Amount.	Clouds. Kind.	Clouds. Direction.	Station pressure.	Precipitation. Last previous ended.	Precipitation. First subsequent began.
Tatoosh Island, Wash. (continued)	13	R.O.Y.G.B.V.	Bright	4 1	Ci. St. A. St.	s. s.			
	13	R.Y.B	Dim						
	14	Y	Dim	4 2	Ci. Cu. St.	w. w.	Rising	D. N. a., 14th	6:56 a. m., 14th.
	14	R.B	Dim	Few. 7	A. St. St.	w. w.	Rising	D. N. a., 14th	6:56 a. m., 14th.
	14	R.Y.B	Bright	1 4	Ci. St. Cu.	 s.	Falling	7:50 a. m., 14th	12:05 p. m., 14th.
	15	W	Dim	2 Few.	Ci. St. A. St.		Falling	12:25 p. m., 14th	4:05 a. m., 16th.
	15	Y	Dim	Few. 2	Ci. St. A. St.				
	15	R. O. Y. G. V.	Brilliant	9	A. St.	s.	Falling	12:25 p. m., 14th	4:05 a. m., 16th.
	15	R. B	Dim	2 7	Ci. St. A. St.	w. w.			
	15	R. Y. B	Bright	8 1	Ci. St. A. St.	w. w.			
	15	R. O. Y. G. V.	Brilliant	9	A. St.	ssw.			
	15	W	Bright	8 1	Ci. St. A. St.	w. w.			
	15	O	Dim	1 4	Ci. St. Ci. Cu.	s. s.	Falling	12:25 p. m., 14th	4:05 a. m., 16th.
	15	R. Y. B	Bright	2 3	Ci. St. A. St.	s. s.			
	17	O	Dim	9	St.	s.	Falling	6:55 a. m., 17th	11:01 a. m., 17th.
	17	R. B	Dim	4 5	Ci. St. St.	 s.	Stationary	12:55 p. m., 17th	4:20 p. m., 17th.
	18	W	Dim	6 3	A. St. St.	sw. s.	Rising	D. N., a., 18th	9:15 a. m., 18th.
	18	O	Dim	5 4	A. St. St.	s. s.	Rising	D. N., a., 18th	9:15 a. m., 18th.
	18	R.O.Y.G.B.V.	Brilliant	5 4	Ci. St. St.	 s.	Rising	10:28 a. m., 18th	1:48 p. m., 18th.
	18	R. B	Dim	5 1	Ci. St. Cu.	 s.			
	18	W	Dim						
	18	O	Dim	5 4	Ci. St. St.	 s.			
	18	R. B	Dim	6 3	Ci. St. St.	 s.			
	19	R. Y. B	Bright	Few. 6	Ci. St. St.	sw. s.	Rising	3:10 p. m., 19th	6:24 p. m., 19th.
	19	R.O.Y.G.B.V.	Brilliant						
	21	R. O. Y. G. V.	Bright	4 1	Ci. St. Cu.	nw. w.	Falling	10:55 a. m., 21st	4:01 a. m., 24th.
	21	R. Y. B	Dim						
	21	W	Dim	6 1	Ci. St. Cu.	nw. nw.			
	21	O	Dim	5 1	Ci. St. Cu.	nw. w.			
	22	O	Dim	3	A. St.	nw.	Stationary	10:55 a. m., 21st	4:01 a. m., 24th.
	22	R. B. W	Dim						
	23	O	Dim	2	Ci.	s.	Falling	10:55 a. m., 21st	4:01 a. m., 24th.
	26	R. O. Y. V	Bright	4 5	A. St. St. Cu.	w. w.	Falling	5:50 a. m., 25th	D. N., a., 27th.
	29	R. O. Y. G. V.	Brilliant	1 Few.	Ci. St. Cu.	w. e.	Falling	D. N., P., 28th	D. N., P., 30th.
	29	R.O.Y.G.B.V.	Brilliant	6 Few.	Ci. St. Cu.	w. 			
	29	R.O.Y.G.B.V.	Brilliant						
	29	V	Dim	6 Few.	Ci. St. Cu.	w. 			
	29	R. Y	Dim	5 Few.	Ci. St. Cu.	w. 			
	29	R. Y	Dim						
	29	Y	Bright	3	Ci. St.	w.			
	30	R. O. W	Dim	Few.	A. St.	w.	Falling	D. N., P., 28th	D. N., P., 30th.
York, N. Y	3	R. O. Y	Bright	2 7	Ci. Ci. St.	 w.	Falling	D. N., a., 1st	1:00 a. m., 4th.
	3	W	Dim						
	5	R. W	Dim	6 2	Ci. St. St. Cu.	w. sw.	Falling	D. N., a., 5th	3:00 p. m., 6th.
	6	W	Dim	4 5	Ci. St. A. St.	w. w.	Falling	D. N., a., 5th	3:00 p. m., 6th.
	14	R. O. Y. W	Brilliant	2	Ci.	w.	Stationary	5:00 p. m., 13th	4:00 p. m., 15th.
	19	Y	Dim	1	Ci. St.	w.	Stationary	8:30 a. m., 18th	1:30 p. m., 20th.
	19	R. O. Y	Bright						
	22			5	Ci.	nw.	Falling	4:00 p. m., 20th	D. N., P., 23d.
	23		Brilliant	10	Ci. St.	w.	Falling	4:00 p. m., 20th	D. N., P., 23d.

† Beginning with part nearest sun or moon. R, red; O, orange, etc.

SOLAR AND SKY RADIATION MEASUREMENTS DURING APRIL, 1919.

By HERBERT H. KIMBALL, Professor of Meteorology, in Charge.

[Dated: Solar Radiation Investigations Section, Washington, May 28, 1919.]

For a description of instrumental exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1919, **47**:4.

The monthly means and departures from normal in Table 1 show that the radiation measurements obtained averaged slightly above the normal. On account of the unusual amount of cloudiness, however, but few measurements were made at any of the stations.

With the return of Assistant Observer E. L. Hardy from military service to Santa Fe, radiation measurements were resumed at that station at the end of the month.

Table 3 shows a normal amount of radiation for April at Washington, but deficiencies of 18 and 16 per cent, respectively, at Madison and Lincoln. Most of the deficiency at Lincoln occurred during the third decade.

An error in computing the Madison normals for the last decade of March, 1919, made the deficiency for that month appear to be 980 instead of 764 calories and the deficiency since the first of the year 2,344 instead of 2,128 calories. This latter value has been used in determining the deficiency up to the end of April.

Skylight polarization measurements obtained on five days at Washington give a mean of 56 per cent, with a maximum of 64 per cent on the 19th. These are average values for Washington in April. At Madison, measurements obtained on three days give a mean of 60 per cent, with a maximum of 66 per cent on the 26th.

TABLE 1.—*Solar radiation intensities during April, 1919.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Apr. 2			0.91							
3	1.24	1.18	1.13							
8			0.78	0.73	0.69	0.66	0.60			
9			0.95	0.80	0.66	0.54				
12		1.21								
19	1.45	1.37	1.24	1.12	1.03	0.96	0.89	0.83	0.78	0.73
21				0.91	0.85	0.79				
22						0.89	0.84	0.79	0.76	0.72
23		1.06	0.89	0.75	0.63	0.53				
24			1.25							
25	1.37									
Monthly means	**1.35**	**1.20**	**1.02**	**0.86**	**0.77**	**0.73**	**0.78**	**(0.81)**	**(0.77)**	**(0.72)**
Departure from 11-year normal	**−0.02**	**+0.03**	**−0.03**	**−0.08**	**−0.09**	**−0.06**	**+0.05**	**+0.08**	**+0.09**	**+0.05**
P. M.										
Apr. 19		1.31	1.12	1.05	0.97	0.90	0.85	0.79	0.71	0.67
21		1.42	1.24	1.13	1.05	0.94	0.88	0.81	0.75	0.70
Monthly means		**(1.36)**	**(1.18)**	**(1.09)**	**(1.01)**	**(0.92)**	**(0.86)**	**(0.80)**	**(0.73)**	**(0.68)**
Departure from 11-year normal		**+0.14**	**+0.10**	**+0.09**	**+0.10**	**+0.07**	**+0.08**	**+0.14**	**+0.13**	**±0.00**

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TABLE 1.—*Solar radiation intensities during April, 1919*—Continued.

[Gram-calories per minute per square centimeter of normal surface.]

Madison, Wis.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Apr. 1			1.30							
25	1.54	1.44	1.35	1.26	1.18	1.15	1.06	0.99	0.93	
26	1.55	1.45	1.38	1.30	1.22	1.15	1.10	1.04	0.99	
Monthly means	**(1.54)**	**(1.44)**	**1.34**	**(1.28)**	**(1.20)**	**(1.15)**	**(1.08)**	**(1.02)**	**(0.96)**	
Departure from 9-year normal	**+0.14**	**+0.10**	**+0.11**	**+0.14**	**+0.10**	**+0.04**	**+0.03**	**+0.03**	**+0.02**	
P. M.										
Apr. 22		1.10								
25		1.40	1.24	1.16	1.05	0.95	0.86	0.77	0.70	
26		1.39								
Monthly means		**1.30**	**(1.24)**	**(1.16)**	**(1.05)**	**(0.95)**	**(0.86)**	**(0.77)**	**(0.70)**	
Departure from 9-year normal		**−0.06**	**−0.03**	**−0.02**	**−0.04**	**−0.10**	**−0.06**			

Lincoln, Nebr.

Date.	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.										
Apr. 1		1.26								
11		1.29								
12		1.34	1.18							
16		1.34	1.24	1.15	1.07					
17	1.53	1.43	1.34	1.25	1.16	1.14				
Monthly means	**(1.53)**	**1.33**	**1.25**	**(1.20)**	**(1.12)**	**(1.14)**				
Departures from 4-year normal	**+0.03**	**−0.02**	**+0.01**	**+0.07**	**+0.09**	**+0.20**				
P. M.										
Apr. 12		1.34	1.21	1.14	1.05	0.96	0.88	0.80	0.72	
17		1.42	1.31	1.20	1.10	1.00				
Monthly means		**(1.38)**	**(1.26)**	**(1.17)**	**(1.08)**	**(0.98)**	**(0.88)**	**(0.80)**	**(0.72)**	
Departures from 4-year normal		**+0.06**	**+0.08**	**+0.09**	**+0.08**	**+0.07**	**+0.02**	**−0.03**	**−0.03**	

Santa Fe, N. Mex.

Date.	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.										
Apr. 30	1.46	1.38	1.31	1.20	1.10	1.01				
P. M.										
Apr. 23			1.25							

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Dates.	8a.m.	8p.m.	Dates.	8a.m.	8p.m.	Dates.	8a.m.	8p.m.	Dates.	8a.m.	8p.m.
1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*
Apr. 2	1.88	2.87	Apr. 1	2.26	2.36	Apr. 1	3.99	4.57	Apr. 23	5.16	7.57
3	3.00	3.99	22	6.76	7.29	11	4.17	5.36	30	5.16	4.17
8	9.47	8.18	25	2.16	3.00	12	5.79	5.79			
9	8.81	8.81	26	2.26	3.45	16	4.17	3.99			
12	8.81	7.29				17	3.99	2.74			
19	4.17	4.57									
21	6.76	3.99									
22	4.75	5.16									
23	6.27	7.87									
24	11.81	3.15									
25	2.36	2.26									

TABLE 3.—*Daily totals and departures of solar and sky radiation during April, 1919.*

[Gram—calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Apr. 1	340	554	319	-35	174	-106	-35	174	-106
2	380	299	429	3	-83	5	-32	91	-101
3	510	86	176	130	-298	-247	98	-207	-348
4	167	235	586	-215	-151	164	-117	-358	-184
5	289	290	462	-96	-98	41	-213	-456	-143
6	502	401	329	115	11	-91	-98	-445	-234
7	356	110	530	-34	-281	111	-132	-726	-123
8	430	501	356	38	108	-62	-94	-618	-185
9	516	117	69	121	-277	-348	27	-895	-533
10	368	169	288	-29	-227	-128	-2	-1,122	-661
11	81	148	524	-319	-249	109	-321	-1,371	-552
12	414	126	643	12	-273	229	-309	-1,644	-323
13	472	524	166	67	124	-247	-242	-1,520	-570
14	273	93	125	-134	-309	-287	-376	-1,829	-857
15	214	48	128	-196	-356	-283	-572	-2,185	-1,140
16	102	85	492	-311	-322	79	-883	-2,507	-1,061
17	156	416	729	-260	6	314	-1,143	-2,501	-747
18	313	580	619	-106	166	202	-1,249	-2,335	-545
19	655	402	354	233	-15	-65	-1,016	-2,350	-610
20	500	616	661	75	196	240	-941	-2,154	-370
Decade departure							**-939**	**-1,032**	**291**
21	623	607	181	194	184	-242	-747	-1,970	-612
22	592	463	548	160	36	123	-587	-1,934	-489
23	589	403	109	154	-27	-18	-433	-1,961	-507
24	480	448	321	42	15	-108	-391	-1,946	-615
25	565	694	564	124	258	133	-267	-1,688	-482
26	468	681	143	24	243	-292	-243	-1,445	-774
27	694	87	138	246	-353	-301	3	-1,798	-1,075
28	278	384	113	-173	-59	-330	-170	-1,857	-1,405
29	586	380	64	132	-65	-383	-38	-1,922	-1,788
30	468	95	213	11	-352	-238	-27	-2,274	-2,026
Decade departure							**914**	**-120**	**-1,656**
Excess or deficiency since first of year: gr.-cal							**-539**	**-4,402**	**-3,375**
Excess or deficiency since first of year: per cent							**-1.6**	**-12.9**	**-8.6**

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By Dr. C. G. ABBOT.

[Dated: Astrophysical Observatory, Smithsonian Institution, Washington, May 28, 1919.]

In continuation of the publication begun in February, I communicate the following results of the measurements of the solar constant of radiation which were made by the Smithsonian observers, Messrs, A. F. Moore and L. H. Abbot, at Calama, Chile, in the month of March, 1919.

The arrangement of the observations in the table is the same as that employed in the preceding communications, and is fully explained in the MONTHLY WEATHER REVIEW for February, 1919.

TABLE 1.—*Measurements of the solar constant of radiation at Calama, Chile.*

Date.	Solar Const.	Grade.	Transmission coefficient at 0.5 microns.	Humidity air mass 3.			Remarks.
				ρ/ρ_{sc}	V. P.	Rel. Hum.	
	cal.				cm.	%	
A. M. Mar. 1	1.952	VG−	0.771	0.253	0.75	60	Considerable cirri in north and east.
P. M. Mar. 3	1.949	VG	.848	.367	.58	29	Considerable cirri and cumuli in east, with line of small cirrocumuli low in west.
5	2.015	G−	.840	.400	.48	21	Considerable cirri in east, north, south and low in west.
6	1.931	E−	.856	.473	.36	16	Cumuli low in east and cirri in south and west.
A. M. Mar. 9	1.938	G	.828	.360	.24	22	Cirri spread over most of sky.
10	1.916	VG−	.844	.414	.29	26	Some cirri around horizon in north and east with large patch just below sun.
P. M. Mar. 13	1.981	P+	.846	.397	.44	22	Considerable cirri in east. More coming in northwest.
A. M. Mar. 17	1.905	VG−	.837	.352	.53	49	
18	1.949	VG−	.851	.457	.35	35	
19	1.934	VG+	.855	.406	.37	35	
21	1.891	VG+	.852	.356	.49	56	
25	1.942	VG	.849	.368	.37	31	Cirri scattered over large part of east and west.
26	1.938	E−	.868	.508	.29	23	Cloudless except distant cirri in northeast.
28	1.955	VG+	.861	.500	.31	29	Considerable cirri in west.
30	1.942	VG+	.843	.335	.46	46	Considerable cirrocumuli in west and south. Small patches also in east.
31	1.913	VG+	.844	.325	.52	50	

THE WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

GENERAL CONDITIONS.

A. J. HENRY, Meteorologist.

The distribution of mean pressure in the Northern Hemisphere for April indicates the beginning of the dissolution of the great continental highs and the building of highs over oceanic areas. The Iceland LOW of the North Atlantic and the Aleutian LOW of the North Pacific, respectively, are still in evidence, although the former now extends southwestward almost to the Canadian Maritime Provinces, so far, indeed, that the winds of northeastern United States come within its control. The winds of the Atlantic north of about latitude 35° are also controlled by the Iceland LOW. Elsewhere over the North American Continent the winds are variable.

April, 1919, was a month without decided variations from the normal in any part of the area under consideration. Such variations as did occur were as a rule in the opposite sense with the result that the month considered, as a whole, was devoid of conspicuous departures.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

April was a quiet month on the North Pacific Ocean, devoid of any unusual meteorological features. Occasional gales have been reported, but with only one or two exceptions these were of moderate force. The Dutch steamship *Nias* encountered stormy weather about the 21st in latitude 40° N., longitude 160–165° E. The wind attained a force of 10 from the northwest. Considerable fog was experienced south of the Aleutians during the second decade.

NORTH AMERICA.

By A. J. HENRY.

The month was less stormy than usual, and the variations in temperature and precipitation were for the most part such as might be expected during a transition month. Rainfall in the United States east of the Rocky Mountains was fairly abundant, and there were no destructive periods of low temperature, although low temperature with killing frost occurred during the third decade of the month in northeastern districts.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The atmospheric conditions for April, 1919, did not differ materially from those of the previous month, with the average pressure over practically the entire ocean apparently slightly above the normal, although not enough vessel reports were received in time to determine these facts accurately.

The number of days on which gales were reported were, as a rule, also less than usual, as only in two 5-degree squares were they recorded on more than two days.

From the 1st to the 3d there was a slight disturbance off the American coast, while the Azores HIGH was fairly well developed, and light to moderate winds were the rule over practically the entire ocean. On the 4th the LOW began to fill in, the HIGH remaining nearly stationary in intensity and position; the conditions of the wind and weather had changed but little, except that two vessels between the 35th and 45th parallels and the 40th and 45th meridians reported moderate gales accompanied by rain. From the 5th to the 8th the circulation of the air was comparatively sluggish, with light to moderate winds and fog off the banks of Newfoundland on the 7th and 8th. On the 9th there was a well developed LOW over the western part of the steamer lanes, and moderate gales were encountered over the ocean between the 35th and 45th parallels and the 35th and 48th meridians. This LOW moved eastward with a fair rate of speed, increasing in intensity, as on the 10th one vessel near latitude 48°, longitude 25°, encountered a southerly gale of over 50 miles an hour.

On the 11th and 12th the pressure was uniformly high over the entire ocean, with no heavy winds, except that on the former date one vessel a short distance north of the Azores experienced a moderate westerly gale. On the 13th there was a disturbance about 10° west of the Irish coast, and westerly to northerly winds of gale force prevailed over the southwesterly quadrants. On the 14th this area of low pressure surrounded the British Isles, the center being near Malin Head, Ireland, where the barometer reading was 28.70 inches. The storm area extended as far west as the 30th meridian, with strong westerly gales accompanied by "hail" in the southerly quadrants.

The observer on board the American steamship *Ampecto* stated in the storm log: "Gale began on the 14th. Lowest barometer, 29.33 inches at 3 a. m. on the 14th; latitude 49° 57′ N., longitude 13° 57′ W. End of gale on the 26th. Highest force of wind, 65 miles an hour. Shift of wind near time of lowest barometer, NW. to N."

This LOW drifted slowly eastward, and on the 15th was central near the east coast of England; moderate to strong northwesterly gales swept the British Isles, although they did not extend as far west as on the previous day.

On the 16th the center of this disturbance was evidently somewhere in central Europe, and a few reports were received showing that moderate westerly gales prevailed off the French coast. On the 17th a fairly well-developed LOW was central near latitude 43°, longitude 40°, and moderate southerly gales were reported in the region between the center and the 45th meridian.

From the 18th to the 24th, high pressure and light to moderate winds were the rule, while fog prevailed off the Banks of Newfoundland during the greater part of this period. On the 25th and 26th a disturbance was central in the Province of Quebec, and moderate westerly and northwesterly gales were reported on both dates between the 35th and 43d parallels, and the 60th meridian and the American coast. On the 27th and 28th heavy northerly winds were encountered off the European coast. The observer on board the British steamship *Northland* stated: "Gale began on the 27th. Lowest barometer, 29.85 inches, nearly all day on the 28th, when the vessel

was in the Irish Channel. End of gale, p. m. of 28th. Highest force of wind, 55 miles an hour. Shift of wind on 28th, W. to WNW. It was in this gale that three American mine sweepers and one naval tug were wrecked near the coast of France with considerable loss of life." (See account of snowstorm in British Isles, below.)

On the 29th the Dutch steamship *Maasdijk* reported a southeasterly gale of over 50 miles an hour near latitude 37°, longitude 48°, although a number of other vessels not far from that locality encountered winds of only moderate force.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

BRITISH ISLES.

April was the fourth month in succession with the mean temperature over the country generally appreciably below normal. The distribution of rainfall was irregular. The general rainfall expressed as a percentage of the normal was: England and Wales, 124; Scotland, 138; Ireland, 72.—*Symons's Meteorological Magazine, May, 1919, p. 45.*

A snowstorm of unusual severity for so late in the season occurred generally over the British Isles on Sunday, April 27, and in the southeast of England the storm was particularly severe. On the morning of Sunday a subsidiary disturbance was developing over the northern portion of the kingdom, and it afterwards moved southward and eastward, over England, the parent disturbance being centered over Denmark. By the evening the subsidiary had assumed more serious proportions than the primary to the northeastward, and was now centered over London and the southeast of England. Snow or hail fell in all districts of the United Kingdom. A region of high barometer extended from Iceland to the Azores which caused strong northerly winds in the rear of the disturbance, and gale force was reached in all districts, while at Holyhead the wind force attained the velocity of 70 miles per hour during Sunday night. In London snow commenced at about 1 p. m. after somewhat heavy rain, and it thoroughly covered the ground by 3 p. m. The depth of snow by the early morning of April 28 in the north of London was 12 to 15 inches and the total precipitation in the 24 hours was 1.6 inches at Camden Square and 1.7 inches at Hampstead. The snowfall occasioned much dislocation of the telegraph and telephone services, and the rapid melting of the snow caused floods in many parts. Temperature on April 27 was abnormally low for so late in the season, the thermometer in London during the afternoon standing at about freezing point. Agriculturists and fruit-growers have suffered somewhat badly.—*Nature (London), May 1, 1919, p. 171.*

DETAILS OF THE WEATHER IN THE UNITED STATES, APRIL, 1919.

CYCLONES AND ANTICYCLONES.

By A. J. HENRY, Meteorologist.

Cyclones.—Six principal, and the same number of secondary, cyclones have been plotted on Chart III. None of these was severe in character and the movement was in no wise exceptional. A majority of the secondaries developed over the southern plateau and Rocky Mountain region and their movement to the northeastward over the great interior valleys was attended by abundant precipitation.

Anticyclones.—Nine anticyclones, the majority of which first appeared over Saskatchewan, have been plotted on Chart II. The general direction of movement was toward the southeast.

THE WEATHER ELEMENTS.

P. C. DAY, Climatologist and Chief of Division.

[Dated: Weather Bureau, Washington, June 2, 1919.]

PRESSURE AND WINDS.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds for April, 1919, are graphically shown on Chart VII, while the means at the several stations, with the departures from the normal, are shown in Tables I and III.

Pressure was decidedly low over the central valleys during the latter part of the first decade, and moderately low about the middle of the second decade over most central and eastern districts where rains were widespread and heavy. During the early part of the third decade pressure was unusually high over the Dakotas and thence southeastward to the lake region, but otherwise the variations were small, this being particularly true in the district west of the Rocky Mountains.

The average pressure for the month was above normal in practically all portions of the United States, except in the far Southwest, where it was slightly below. In Canada, the region of the Great Lakes and portions of the far western Provinces had monthly averages slightly below normal; however, in no case was the departure from the seasonal average greater than 0.10 inch.

The distribution of atmospheric pressure favored southerly winds in most sections from the Rock Mountains eastward, except near the Canadian border, where they were frequently from the North. West of the Rocky Mountains the winds were variable but frequently between Northwest and Southwest points.

TEMPERATURE.

April opened with unseasonably cold weather from the Mississippi Valley eastward, the line of freezing temperature extending as far south as the northern portion of the east Gulf States; and light frosts occurred in the interior of Florida. In the far West the weather was moderately warm for the season. Slowly rising temperature followed in the East, so that by the middle of the first decade moderately warm weather prevailed in nearly all districts. During the latter part of the decade decidedly lower temperature overspread the Central Plains States, but, otherwise, moderately warm weather continued.

The first half of the second decade was marked by generally mild weather in most sections, continuing until about the middle, when warmer weather obtained in the Ohio Valley and Tennessee, and in the far West, particularly in portions of California and Arizona, but considerably lower temperature overspread the Plains States and central Rocky Mountain districts. During the following few days colder weather overspread most eastern districts, while west of the Rockies the temperature continued, as a rule, above the normal. However, by the end of the decade temperatures had risen to somewhat above the seasonal average in most sections of the country.

At the beginning of the third decade the temperature was considerably lower in the Northeastern and Middle Atlantic States, and the weather was warmer over the upper Mississippi Valley and upper Lakes region, and generally mild weather prevailed elsewhere. About the 23d a condition of high pressure and unseasonably low temperature moved from Canada into the border States between the upper Missouri Valley and Lakes region, and during the following three or four days there were sharp falls in temperature over all districts to the southeastward. Freezing temperatures extended to southward of the Ohio River and killing frosts were general in the region indicated, as well as to the southward as far as northern Georgia and western North Carolina. A general warming up followed, the temperature rising above normal in most eastern districts, while it continued moderate west of the Rocky Mountains, and the month closed with seasonable temperatures in practically all districts.

The month as a whole was slightly cooler than the average over the central and southern Great Plains, most of the Gulf States, and in the extreme Northeast. Elsewhere the monthly means were normal or slightly above. The largest departures from the normal occurred in the far Northwest and far Southwest, where they averaged from +3° to +5° a day. In portions of the Southern Plateau region April was the first month with average temperature above normal since October, 1918.

PRECIPITATION.

At the beginning of the month generally fair weather prevailed in most sections. But by the middle of the first decade light showers had occurred in most districts east of the Rocky Mountains. Showery weather obtained during the next few days from the Great Lakes westward to the Pacific and southward to Oklahoma and northern Texas, and during the latter part of the decade precipitation overspread practically all districts east of the Rocky Mountains, the amounts being rather heavy in portions of New Mexico, Oklahoma, Kansas, and locally in the Mississippi Valley, and southeastern and middle Atlantic coast States. Fair weather prevailed in most districts during the early part of the second decade, but about the middle precipitation occurred in practically all districts east of the Mississippi River and as far west as the central Rocky Mountains southwest to central Texas. During the remainder of the decade fair weather prevailed except for light rains locally in the upper Mississippi and Ohio valleys, the Lake region, and the Pacific coast districts.

Early in the third decade local rains occurred in the upper Mississippi and Ohio valleys and northern Plains States, and about the middle rain or snow fell from the central and upper Mississippi Valley eastward, the amounts being moderately heavy at points in northern Ohio and western New York. During the latter part of the decade light rains occurred over most sections from the Mississippi Valley to the Rocky Mountains, and extended later to the Ohio Valley, New York, and New England, but fair weather prevailed in the Southeast and west of the Rocky Mountains. The month closed with generally showery weather in the central and western Gulf States, the Mississippi Valley, Tennessee, North Carolina, Virginia, and the northeastern Canadian Provinces; elsewhere fair weather prevailed.

For the month as a whole precipitation was well distributed over the great agricultural districts, and while not greatly above the normal, the number of days with rain was large over the central valleys, and considerable delay in preparation of the soil for spring planting resulted. In the Southwest, particularly in eastern and northern New Mexico and the adjoining portions of Texas, Oklahoma, and Colorado, the precipitation was unusually heavy, a large part falling as snow during the early part of the month. From the middle and northern Rocky Mountain districts westward to the Pacific the precipitation was nearly everywhere deficient, particularly over the middle Pacific coast section.

The region of heaviest precipitation was along the middle Gulf Coast, where locally the totals for the month exceeded 10 inches, with some unusually heavy falls in short periods. At Pensacola, Fla., on the 10th there was a fall of nearly 9 inches in less than 12 hours. Over considerable areas from northeastern New Mexico to the central portions of Minnesota and Wisconsin the monthly falls ranged from 4 to 6 inches, and similar amounts were reported from portions of the North Pacific Coast.

In Iowa more precipitation fell and more days were rainy in the period, February 1 to April 30, than in any other similar period in the 30 years since statewide records have been compiled, 9.53 inches falling on 28 days, or 3.75 inches, and 9 days, above the respective normals. The precipitation is 165 per cent of the normal. The year 1897 has held the record heretofore, with 8.63 inches and 24 rainy days.

SNOWFALL.

There was generally less snow in the Western States than usual in April, except over the eastern slopes of the Rocky Mountains, where, from Wyoming and South Dakota to the Pan Handle of Texas and central New Mexico, the amounts were unusually large, most of which occurred from the 6th to the 9th, when real winter weather prevailed. During this period heavy snows fell over the western portions of the Plains States, accompanied by high winds and near-blizzard conditions. The drifting snow greatly hampered train and wire communications, delayed farming operations, and was severe on young stock. Over the foothills the snow depth ranged frequently from 6 to 12 inches or more, while in the high elevations of New Mexico the fall amounted to several feet. Over Arizona the comparatively warm weather carried off most of the snow from the mountains, but without any material rise in the streams. The stored water available for irrigation was therefore not materially increased, and the outlook for a sufficient supply of water for irrigation is unfavorable.

RELATIVE HUMIDITY.

For the month as a whole the relative humidity was lower than the seasonal average in most sections east of the Mississippi and south of the Ohio rivers and in the northern and central districts to westward of the Rocky Mountains. From New Mexico and western Texas northward to the Canadian border and northeastward to the Lake region and New England, the relative humidity was above normal. The excesses over the Great Plains were unusually large, ranging locally from 10 to 20 per cent, while the deficiencies in portions of the east Gulf States, and locally in the far West, were nearly as great.

SEVERE STORMS.

Despite the presence of atmospheric pressure and temperature distribution favorable for severe local storms, the month was comparatively free from these visitations. On the 6th three small tornadoes formed in eastern Nebraska. (See pp. 234-236, above.) On the 8th small tornadoes were reported locally in west-central Texas, but without material property loss. In Iowa a small tornado occurred in Clinton County on the afternoon of the 23d, but this was likewise without much property loss.

Average accumulated departures for April, 1919.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	In.	In.	In.	P. Ct.		P. Ct.	
New England	43.4	−0.2	+12.5	2.47	−0.60	+1.50	6.7	+1.1	74	0
Middle Atlantic	51.2	+0.5	+12.4	2.86	−0.20	−0.90	5.7	+0.4	66	− 2
South Atlantic	61.9	+0.7	+ 4.8	1.93	−1.40	−3.40	4.0	−0.2	67	− 4
Florida Peninsula	73.0	−0.6	− 1.2	2.20	+0.30	+3.00	4.1	+0.4	70	− 4
East Gulf	64.2	−0.4	+ 0.1	4.94	+0.90	+3.20	3.9	−1.1	67	− 5
West Gulf	65.5	−0.4	− 0.5	2.64	−0.90	−1.40	4.6	−0.5	72	− 1
Ohio Valley and Tennessee	54.8	+0.2	+ 7.5	3.02	−0.60	−2.50	6.2	+0.8	66	0
Lower Lakes	44.6	−0.6	+12.8	3.84	+1.50	−0.70	7.0	+1.2	73	+ 2
Upper Lakes	41.9	+1.1	+17.5	2.90	+0.60	−0.40	6.5	+0.8	76	+ 3
North Dakota	42.9	+2.2	+16.0	1.51	−0.40	−0.40	5.6	+0.4	70	+ 3
Upper Mississippi Valley	51.0	+0.5	+15.6	3.21	+0.30	−0.40	6.6	+1.3	70	+ 2
Missouri Valley	50.3	−0.2	+16.7	3.30	+0.40	0.00	6.4	+1.1	71	+ 7
Northern slope	45.3	+2.5	+12.7	1.17	−0.40	−1.10	5.3	+0.2	60	0
Middle slope	52.8	−1.0	− 6.0	3.30	−1.10	−1.00	6.2	+1.5	68	+10
Southern slope	61.6	−0.8	− 3.8	2.86	+1.20	+2.80	4.0	−0.4	63	+10
Southern Plateau	59.7	+1.9	− 7.3	0.56	+0.20	−0.10	3.3	+0.5	40	+ 6
Middle Plateau	50.7	+1.8	+ 0.8	0.69	−0.50	−1.60	4.9	+0.8	47	− 1
Northern Plateau	50.8	+1.8	+ 9.2	1.16	−0.20	−0.20	5.9	+0.6	55	− 1
North Pacific	50.2	+1.2	+ 5.1	3.64	+0.40	+2.80	6.4	+0.2	77	+ 1
Middle Pacific	55.0	+1.4	− 0.9	0.82	−1.30	−0.60	4.7	+0.5	69	− 1
South Pacific	59.8	+1.3	+ 2.4	0.16	−0.80	−3.30	4.1	+0.3	71	+ 2

Winds of 50 mis./hr. (22.4 m./sec./), or over, during April, 1919.

Station.	Date.	Velocity.	Direction.	Station.	Date.	Velocity.	Direction.
Alpena, Mich	16	52	ne.	North Head, Wash.	9	62	se.
Block Island, R. I.	25	56	w.	Do	17	55	s.
Buffalo, N. Y	25	52	w.	Do	18	54	s.
Cheyenne, Wyo	5	52	w.	Do	19	60	se.
Do	13	54	w.	Oklahoma, Okla	9	58	w.
Do	14	50	nw.	Pensacola, Fla	10	50	se.
Dallas, Tex	4	51	nw.	Pierre, S. Dak	5	58	nw.
Drexel, Nebr	7	54	s.	Point Reyes Light, Calif	5	65	nw.
Do	22	70	w.	Do	6	54	nw.
Duluth, Minn	7	57	ne.	Do	7	55	nw.
Ellendale, N. Dak	5	54	w.	Do	13	51	nw.
Do	7	50	ne.	Providence, R. I	25	55	w.
El Paso, Tex	6	54	w.	Pueblo, Colo	6	50	w.
Erie, Pa	16	52	se.	St. Louis, Mo	7	50	s.
Green Bay, Wis	7	60	ne.	Salt Lake City, Utah	5	50	nw.
Hatteras, N. C	24	50	n.	Sandusky, Ohio	10	58	sw.
Independence, Calif	5	54	w.	Do	23	52	n.
Do	13	60	nw.	Sandy Hook, N. J.	11	61	s.
Modena, Utah	5	54	sw.	Seattle, Wash	19	50	sw.
Do	13	57	sw.	Tatoosh Island, Wash	10	52	sw.
Mount Tamalpais, Calif	5	66	nw.	Do	15	54	e.
Do	6	68	nw.	Do	19	54	s.
New York, N. Y	24	62	nw.	Toledo, Ohio	10	52	s.
Do	25	61	nw.	Tonopah, Nev	5	53	w.
Do	26	53	nw.	Wichita, Kans	7	52	w.
North Head, Wash.	3	56	se.	Do	19	50	sw.
Do	5	54	nw.				

SPECIAL FORECASTS AND WARNINGS—WEATHER AND CROPS.

WEATHER WARNINGS.

By H. C. FRANKENFIELD, Supervising Forecaster.

[Dated: Weather Bureau, Washington, D. C., May 23, 1919.]

The first warning of the month was issued at 9:30 p. m., April 6. It was an advisory warning to open ports on Lake Michigan for increasing east winds, with rain or snow, on the following day. At the time there was a Colorado disturbance over western Nebraska with a northeastward movement, and strong winds and rains occurred as forecast, with also some severe thundersqualls along the northwest shore.

On the evening of the 8th a southwestern disturbance was central over Texas with a promise of further development to the eastward, and at 10 p. m. southeast storm warnings were ordered along the Gulf coast from Bay St. Louis, Miss., to Carrabelle, Fla. The subsequent movement of the disturbance was more to the northward than had been anticipated, and only fresh winds occurred on the following day. On the morning of the 9th, with the storm center over Oklahoma, advisory warnings of fresh to strong northeast to north winds were sent to open ports on Lake Michigan, and moderately strong winds occurred during the night of the 9th and on the 10th, the warnings having been repeated on the morning of the 10th. By the afternoon of the 10th the disturbance was central over Wisconsin, with a decided pressure fall to the eastward, and at 6 p. m. southwest storm warnings were ordered along the Atlantic Coast from Portland, Me., to Norfolk, Va., for strong southwest winds, to begin by the following morning. At 10:30 p. m. the warnings were extended to Eastport, Me. Strong winds occurred generally as forecast, New York City reporting a velocity of 60 miles an hour from the south on the 11th.

The display of storm warnings on the Great Lakes was resumed for the season on the 15th, and at 10 a. m. of that day northeast storm warnings were ordered for Lakes Michigan and Huron and central and western Lake Erie, and small-craft warnings for Lake Superior. At this time a disturbance that first appeared over Nevada on the morning of the 12th was central over northern Illinois, with a slow, but steady, eastward movement. At 2:30 p. m. advisory warnings for fresh and possibly moderately strong northeast winds were sent to Lake Ontario ports. Strong winds occurred as forecast, and on the morning of the 16th, with the storm center over Ohio in more marked form, northeast warnings were continued on Lake Huron from Alpena to Mackinaw City, Mich., and those on Lake Erie from Cleveland, Ohio, to Erie, Pa., changed to northwest, while southwest warnings were ordered from Buffalo to Oswego, N. Y. Southeast warnings were also ordered along the Atlantic coast from Deleware Breakwater, Del., to Portland, Me., and southwest warnings from Baltimore, Md., to Hatteras, N. C. At 3:30 p. m. northeast warnings were also ordered on extreme eastern Lake Superior, and southeast warnings at 10 p. m. on the Maine coast east of Portland. All of these warnings were justified by the subsequent occurrences.

On the morning of the 23d there was a moderate depression over the Upper Mississippi Valley and the western Upper Lake Region, with a strong and cold high area to the northwestward, and northwest warnings were ordered at 10 a. m. on Lake Superior and on Lake Michigan from Milwaukee, Wis., and Ludington, Mich., northward, strong winds with rain possibly turning to snow being forecast. At 3:30 p. m. the northwest warnings were extended on Lake Huron from Mackinaw City to Alpena, and at 10 p. m., with the disturbance over northeastern Ohio, northwest warnings were also ordered for the balance of Lake Huron and for Lake Erie as far east as Erie, Pa. On the morning of the 24th, with the storm central over Lake Ontario, northwest warnings were ordered for that lake, and at 12 noon for the Atlantic coast from Norfolk to Boston. All of these warnings were fully verified except in the immediate vicinity of Boston.

By the morning of the 25th the storm center had reached southern Maine, and the Atlantic coast warnings were continued from Sandy Hook, N. J., to Boston, and extended northward to Eastport, Me. These warnings were also justified, except on the coast of Maine. There were no other storms during the month, and there were no storms without warnings.

COLD-WAVE AND FROST WARNINGS.

High pressure prevailed over the interior districts east of the Mississippi River on the morning of the 1st, and heavy frosts occurred as far south as the northern portions of Alabama, Georgia, and South Carolina. Frost warnings were then issued for the Southern States as far south as northern Florida and for freezing temperatures into South Carolina, and on the morning of the 2d light frost occurred as far south as central Florida, and freezing temperature to the North Carolina-South Carolina line. Warnings were again issued for freezing temperatures on the morning of the 3d in West Virginia, Virginia, Maryland, and the District of Columbia, and for frosts as far south as central Florida. These warnings were also verified as a whole, although the temperatures in the District of Columbia and eastern Maryland did not quite fall to the freezing point.

On the morning of the 10th warnings of frost, contingent upon clearing weather, were issued for the interior of the East Gulf States and central and western Tennessee, but the fall in temperature was not sufficient and no frosts occurred, although the weather cleared and frosts occurred in Arkansas.

On the morning of the 13th pressure was quite high over the lower Ohio Valley, with cool clear weather, and the forecasts for West Virginia, Virginia, and Maryland contained a warning of possible frost on the following morning. Again no frost occurred owing to the rapid eastward movement of a western depression.

The light frosts on the morning of the 17th over central Tennessee and northern Alabama were not forecast. Frosts were forecast for the morning of the 18th over southern Virginia, the Carolinas, the interior of Alabama and Mississippi, northern and central Georgia, Tennessee, Kentucky, and southern Ohio, and they occurred generally as forecast.

Frosts were also forecast for the morning of the 19th over the Ohio Valley, the lower Lake region, and the Atlantic States from southern New England to North Carolina, and the forecast was correct, except along the Atlantic coast.

Other forecasts for portions of the Atlantic States on the 20th, 21st, 25th, 26th, and 29th were also generally verified.

No cold-wave warnings were issued during the month.

SPECIAL UPPER-AIR FORECASTS.

Special forecasts of surface and upper-air conditions were made daily for the United States Army and Navy and the Post Office Department. These forecasts were found to be of great practical benefit to all concerned, and they have apparently become an established feature of the forecast work. During the month of April Maj. Theodore C. Macaulay, of the United States Army Air Service, completed a coast-to-coast flight in an aeroplane, and upon the completion thereof he forwarded the following telegram to the Chief of the Weather Bureau:

Coast-to-coast and return flight completed eleven thirty today (April 18) covering fifty-five hundred miles in five and one-half days with total flying time of forty-four hours. Sincerely appreciate your valuable cooperation.

MACAULAY.

WARNINGS FROM OTHER DISTRICTS.

Chicago, Ill., Forecast District.—The month was marked by rather frequent storm movement over the forecast district. As a consequence, the temperature was variable, but for the most part considerably above the seasonal normal during the first half of the month and below during the second half. Rainfall was frequent in the Middle States, but, while greater than the monthly normal, excessive amounts were recorded in only a few instances. The outstanding feature of the entire month was the small amount of sunshine in various portions of the district, and especially during the second half of the month.

Aside from the regular forecasts the warnings during the month were confined to advices as to probable frosts. These warnings were necessary at the beginning of the month only for southern Missouri, extreme southern Illinois, and southeastern Kansas, because the condition of vegetation in other sections had not advanced to the danger point. At the close of the month, however, this condition was reached all over the region, except in the more northerly and westerly sections.

Frost and freezing-temperature warnings were issued for Kansas on the 7th, 8th, 9th, and 10th, following the movement eastward of two well-marked low-pressure areas across the Middle States, and on the 9th for western Missouri, and again on the 10th for the entire State of Missouri, and these were almost fully verified.

On the 15th, 16th, and 17th similar warnings were issued for Kansas, on the 15th for west and central Missouri, and on the 16th and 17th for all Missouri and southern Illinois, following the movement eastward of another disturbance. These, too, were verified, with the exception of the last warning for west and central Kansas, as that State by the morning of the 18th had come under the influence of a northwestern low-pressure area, which caused a shift of the winds to southerly.

Warnings were issued on the 21st for southeastern Wisconsin and northeastern Illinois as a high-pressure area approached the Lake region from the upper Mississippi Valley, and these were fully verified. By the morning of the 23d an area of high pressure of great magnitude had developed in the Northwest, and this pushed slowly southeastward over the Middle States, producing abnormally low temperatures over a vast area. As this condition was well marked, warnings of frost and freezing temperature were issued well in advance of the wave, and it was not until the evening of the 26th that the influence of the high terminated in the eastern portion of the forecast district.

Another high-pressure area, but of lesser magnitude than the preceding one, pushed down from Manitoba over the upper Mississippi Valley and Great Lakes region during the 27th–28th. By that time, even, vegetation in the far Northwest had not developed sufficiently to require warnings, but on the 28th advices were sent to Wisconsin, Minnesota, and northeastern Iowa, with ensuing verifications, with the exception of the portion of Iowa indicated, where cloudy weather developed.

Warnings were issued for South Dakota and Nebraska and western Kansas on the 30th in advance of another northwestern high-pressure area, but the verification of these warnings was confined to South Dakota and western and central Nebraska as the high lost intensity and was followed immediately by a barometric disturbance.

While these warnings were given wide distribution, no estimate of their value can be well determined. It is probable, however, that garden truck was protected to a large extent.

A special wind and weather forecast was sent to the observer at Helena, Mont., April 24 for Saturday the 26th, in connection with the "Flying Circus" of the United States Army aviators advertising the Fifth Liberty loan, and the prediction of fair weather with moderate winds was fortunately verified. The observer at Helena has reported that the forecast was much appreciated.—*H. J. Cox.*

New Orleans, La., Forecast District.—Storm warnings ordered 9:20 p. m., April 8, for the Texas coast, Velasco to Port Arthur, were verified.

Small-craft warnings were displayed on the Texas coast on the 6th and on the Louisiana coast on the 9th.

Cold-wave warnings displayed over central and eastern Oklahoma and northwestern Arkansas, April 9, were partially verified.

Fire-weather warnings were issued for Oklahoma and Arkansas on April 6 and were justified.—*I. M. Cline.*

Denver, Colo., Forecast District.—Warnings of frost or freezing temperature were issued on eight days during the first half of April and on four days during the latter half. The warnings were fully verified in nearly all cases. While freezing temperatures occurred in the northern half of the district, vegetation was too backward to be injured. In the latter half of the month higher temperatures prevailed and fruits made rapid progress. The frosts were light and the damage, if any, was slight.—*F. H. Brandenburg.*

San Francisco, Cal., Forecast District.—There were no severe storms during April in the San Francisco Forecast District. Temperatures averaged slightly above normal and the rainfall was deficient, except in western Oregon, western Washington, extreme northwestern California, and southwestern Idaho.

During the first decade barometric pressure was unusually low over the Aleutian Islands, and it was necessary to display storm warnings on the 3d at north Pacific coast stations and on the 5th along the northern California coast, and small-craft warnings on the 15th and 19th at northern coast stations. The Los Angeles official hoisted storm warnings on the 6th in his district, which were verified.

During the middle decade barometric pressure was unusually high over the Aleutian Islands, which resulted for the most part in fair weather in this district. There were numerous frosty mornings in the North Pacific States and on two or three mornings frost formed in northern California. Warnings for same were issued in every instance.

During the last decade barometric pressure over the Aleutian Islands was relatively low, and rain, with unsettled weather, prevailed for several days in the northern portion of the district, including northern California.

Live-stock warnings were issued on the 24th to places in the North Pacific States, and they were fully verified — *E. A. Beals.*

RIVERS AND FLOODS, APRIL, 1919.

ALFRED J. HENRY, Meteorologist in Charge.

Floods on the Atlantic drainage.—Owing to the light snow cover and the absence of torrential rains, there were no destructive floods in this region during the month. In New England the Connecticut River reached flood stage at two points only, viz, White River Junction, Vermont and Hartford, Conn. The rivers of the South Atlantic States did not reach flood stage, except on the Santee, where a moderate flood prevailed about the middle of the month below the junction of the Wateree and the Congaree. The details are shown in Table I.

East Gulf drainage.—In this district, likewise, only light local floods were recorded. The Tombigbee River of Alabama was above the flood stage on April 2; the Pearl River of Mississippi was above flood stage on April 19. No material damage resulted.

West Gulf drainage.—The upper Trinity was in flood on several days of the month, and the Rio Grande in New Mexico reached flood stage during the last decade of the month.

Mississippi drainage— Mississippi River.—For the third consecutive year there has been no flood of consequence in the Mississippi below Cairo and only light to moderate floods above St. Louis. Agricultural lands along that portion of the stream between Davenport, Iowa, and Louisiana, Mo., suffered more or less by overflow in 1915, 1916, and 1918. In 1918 the Indian Grave Levee broke at a stage of 17.4 feet on the Quincy, Ill., gage. Since a stage of 17.5 feet was reached at Quincy on April 28, much apprehension was felt for the safety of the levees and radical measures were taken to reinforce weak spots.

The natural conditions favorable to high water in this section of the Mississippi are the occurrence of heavy rains extending over two or three days in eastern Iowa or moderate rains extending over a longer period, the run-off from which may or may not synchronize with that from melting snow or heavy rain on the Mississippi drainage above Dubuque, Iowa. The magnitude of the floods will depend largely upon the simultaneity of the run-off from the two regions. The rainfall of the current season has caused high water quite generally in eastern Iowa rivers and along the Mississippi from Dubuque, Iowa, to Louisiana, Mo. The slope of the Mississippi in the stretch from Quincy, Ill., to Louisiana, Mo., is small; therefore flood waters run off slowly. Following is a summary of duration of flood stages taken from Table IV.

Station.	From—	To—
Keokuk, Iowa	Apr. 21	Continued at end of month.
Warsaw, Ill	Apr. 22	Do.
Quincy, Ill	Apr. 18	Do.
Hannibal, Mo	Apr. 13	Do.
Louisiana, Mo	Apr. 17	Do.

Along the stretch of the river represented by the above-named stations, farming the rich bottom lands is a more or less hazardous proposition. Yet, by reason of the great fertility of the soil, the incentive to take the risk of loss by overflow is so compelling that, except for such times as an early overflow prevents the putting in of crops, the lands are always under cultivation.

The Mississippi below Cairo was at flood stage on the first of the month between Memphis and Arkansas City, Ark. The crest of this rise reached Vicksburg, Miss., on the 15th, and passed thence slowly down stream as a moderate freshet. The only overflow so far recorded was that of about 400 square miles in Mississippi, mostly between the Yazoo and Mississippi rivers.

The lower stretches of the Illinois River were in flood the entire month; that portion above Peoria from the 1st to the 15th. Timely warnings were issued in all cases.

Approximate loss by floods, April, 1919.

District.	Tangible property.	Crops.		Live stock.	Suspension of business.	Money value of warnings.
		Present.	Prospective.			
Davenport, Iowa	$20,000				$2,500	$12,000
Vicksburg, Miss			$40,000			

TABLE I.—*Flood stages in the Atlantic drainage during the month of April, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Connecticut:	*Feet.*			*Feet.*	
White River Junction, Vt	13	12	16	15.5	14
Hartford, Conn	16	(**)	1	19.8	†30
Hudson:					
Albany, N. Y	12			10.9	13
West Canada Creek:					
Trenton Falls, N. Y	8			7.5	12
Santee:					
Rimini, S. C	12	14	17	12.5	15
Ferguson S. C	12	16	20	12.2	17-19

** Continued from March. † March.

TABLE II.—*Flood stages in the East Gulf drainage during the month of April, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Tombigbee:	*Feet.*			*Feet.*	
Demopolis, Ala	39	(**)	2	44.4	1
Pearl:					
Jackson, Miss	20	19	21	21.0	20
Columbia, Miss	18			17.9	19
West Pearl:					
Pearl River, La	13	(**)	8	14.9	†27
		16	27	14.3	23

** Continued from March. † March.

TABLE III.—*Flood stage in the Great Lakes drainage during the month of April, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
St. Joseph:	*Feet.*			*Feet.*	
Montpelier, Ohio	10	16	19	12.4	17
Sandusky:					
Upper Sandusky, Ohio	13			11.6	17
Chippewa:					
Mount Pleasant, Mich	11			9.3	17-18
Grand:					
Eaton Rapids, Mich	5	17	19	5.4	18
Lansing, Mich	11			10.7	18
Grand Ledge, Mich	6	17	19	7.2	18
East Lansing, Mich	8	17	19	9.6	17
Diamondale, Mich	5			4.4	18

TABLE IV.—*Flood stages in the Mississippi drainage during the month of April, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Scioto:	*Feet.*			*Feet.*	
La Rue, Ohio	11	17	17	11.4	17
Circleville, Ohio	7			6.5	18
Wabash:					
Mount Carmel, Ill	15			14.8	1
Ohio:					
Cairo, Ill	45			42.2	1
Mississippi:					
St. Paul, Minn	14			13.8	22
La Crosse, Wis	12			11.7	16-17
Stillwater, Wis	12	(**)	5	13.5	†31
Dubuque, Iowa	18			16.6	22-23
Clinton, Iowa	16			15.4	24
Le Claire, Iowa	10	21	28	10.7	25
Davenport, Iowa	15			13.7	25
Muscatine, Iowa	16			15.8	26
Keokuk, Iowa	14	21	(*)	16.2	27-28
Warsaw, Ill	17	22	(*)	19.2	27
Quincy, Ill	14	18	(*)	17.5	28
Hannibal, Mo	13	13	(*)	17.9	28
Louisiana, Mo	12	17	(*)	15.8	29
Grafton, Ill	18	29	(*)	18.6	30
Alton, Ill	21			20.1	30
New Madrid, Mo	34	(**)	1	34.3	1
Memphis, Tenn	35	(**)	3	36.7	1
Helena, Ark	42	(**)	8	46.2	1
Arkansas City, Ark	42	(**)	15	49.4	5- 6
Greenville, Miss	42			41.7	5- 7
Vicksburg, Miss	45	4	15	46.0	9-12
Natchez, Miss	46			45.7	12-14
Baton Rouge, La	35			34.5	16
Donaldsonville, La	28			27.0	17
New Orleans, La	18			17.1	12
Wisconsin:					
Knowlton, Wis	12			13.4	12
Des Moines:					
Ottumwa, Iowa	10	24	27	12.0	26
Illinois:					
Peru, Ill	14	(**)	20	17.5	1
Henry, Ill	7	(**)	(*)	12.9	1
Peoria, Ill	16	(**)	15	20.0	1
Havana, Ill	14	(**)	17	17.9	1
Beardstown, Ill	12	(**)	(*)	19.1	1
Pearl, Ill	12	(**)	(*)	16.3	1
Grand:					
Chillicothe	18	11	14	21.8	13
Missouri:					
Brunswick, Mo	10	12	15	11.4	14
Ree, N. Dak	12			11.1	5
Bismarck, N. Dak	14	6	6	14.6	6
Kansas City, Mo	22			20.7	13
St. Francis:					
Marked Tree, Ark	17	(**)	10	17.1	1- 6
Yazoo:					
Greenwood, Miss	36			34.7	2
Yazoo City, Miss	25	8	(*)	28.9	17-20
Atchafalaya:					
Simmesport, La	41			38.2	17-19
Melville, La	37	13	21	37.4	17-18
James:					
Huron, S. Dak	9	(**)	4	11.0	1
Little Arkansas:					
Sedgwick, Kans	18			17.0	29
Cache:					
Jelks, Ark	9	(**)	10	9.8	1
Sulphur:					
Ringo Crossing, Tex	20			18.2	19

** Continued from March. * Continued into May. † March

TABLE V.—*Flood stages in the West Gulf drainage during the month of April, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Trinity:	*Feet.*			*Feet.*	
Dallas, Tex	25	(**)	2	30.7	1
		9	13	31.5	11-12
Trinidad, Tex	28	16	19	29.6	18
Sabine:					
Bon Wier, Tex	20			18.4	1
Guadalupe:					
Victoria, Tex	16	6	6	18.1	6
Rio Grande:					
Albuquerque, N. Mex	4			3.8	26-30
San Marcial, N. Mex	14	22	(*)	15.3	28-30
North Fork, Gunnison:					
Paonia, Colo	8			7.7	24-25

** Continued from March. * Continued into May.

MEAN LAKE LEVELS DURING APRIL, 1919.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., May 5, 1919.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.*			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during April, 1919:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.02	581.02	573.05	246.43
Above or below—				
Mean stage of March, 1919	+0.13	+0.28	+0.57	+0.42
Mean stage of April, 1918	+0.58	−0.39	+0.79	−0.74
Average stage for April, last 10 years	+0.45	+0.84	+0.75	+0.09
Highest recorded April stage	−0.67	−2.21	−1.13	−2.00
Lowest recorded April stage	+1.48	+1.80	+1.79	+1.59
Average relation of the April level to—				
March level		+0.3	+0.6	+0.7
May level		−0.3	−0.4	−0.3

* Lake St. Clair's level: In April, 575.88 feet.

EFFECT OF WEATHER ON CROPS, APRIL, 1919.

By J. WARREN SMITH, Meteorologist in Charge.

Farm work.—The month was generally favorable for outdoor operations from the Rocky Mountains westward and farm work made good progress in those districts. It was also mostly favorable in the Southern States, but frequent rains and continued wet soil interrupted farming operations in many central and northern localities, and at the close of the month work was generally behind the seasonal average in those sections.

Winter grains.—The weather continued favorable in most districts for the development of winter grains and winter wheat, oats, rye, and barley made satisfactory progress during the month; these crops were generally in good to excellent condition at its close. Growth of winter wheat was somewhat too rank in portions of the Central Plains region and lower Missouri Valley and some lodging was reported in eastern Kansas; rain was needed in some southern localities at the end of the month.

Spring crops.—Conditions were generally favorable in the spring-wheat area and seeding spring wheat had progressed to the northern limits of the belt at the close of the month, although there was some delay by wet soil in Minnesota and Wisconsin. The early sown grain in the central and southern portions of the belt made good progress during the latter part of the month. The preparation of corn ground was considerably delayed in many central districts, especially in portions of the Great Plains area, and it was too cool for satisfactory germination of corn the latter part of the month. There was some frost damage to this crop during the last week in Tennessee and the central Appalachian Mountain States. Oats seeding was delayed by frequent rains and wet soil in many of the important producing areas.

The first half of the month was mostly favorable for cotton planting, germination of seed, and growth of the early planted cotton in most of the eastern portion of the belt, but rains and wet soil were unfavorable to the westward of the Mississippi River. The last half was favorable for farm work generally, and planting and replanting made good progress, but the cool weather was decidedly unfavorable for germination and growth in most localities, while frost on the 26th and 27th damaged the early crop in the Carolinas.

Truck crops.—The first part of the month was too cool and wet for truck crops in much of the South, and there was some frost damage early in the month as far south as the interior of northern Florida. Thereafter, the weather was fairly favorable for truck in most southern districts, but it continued too wet for planting in many central localities, and in the latter part of the month there was some damage to potatoes and other truck from the Ohio Valley eastward.

Live stock.—Weather conditions continued favorable for pastures and ranges throughout the month in practically all sections of the country, and stock generally did well, although at the close of the month grass needed more moisture locally in the southeast and in the Rocky Mountain States and far southwest. Cattle and sheep were moving to summer ranges in the Rocky Mountain districts.

Fruits.—Fruits made satisfactory progress in most districts under generally favorable weather conditions, although there was some damage by frost and freezing temperatures in central districts and also in portions of the Atlantic and northern east Gulf States. In the Lake region the development of fruit buds was checked by cool weather in the latter part of the month.

CLIMATOLOGICAL TABLES.

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, April, 1919.

Section.	Temperature.		Monthly extremes.						Precipitation.		Greatest monthly.		Least monthly.	
	Section average.	Departure from the normal.	Station.	Highest.	Date.	Station.	Lowest.	Date.	Section average.	Departure from the normal.	Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	62.6	−0.5	Ozark	92	24	St. Bernard	24	2	3.50	−0.86	Citronelle	9.55	Birmingham	1.55
Arizona	61.0	+2.2	Sentinel	104	17	2 stations	18	6†	0.64	−0.13	Naco	2.42	4 stations	0.00
Arkansas	61.6	+0.5	Texarkana	95	24	Calico Rock	24	16	3.56	−1.27	Crossett	7.02	Whitecliffs	0.33
California	57.3	+0.3	2 stations	104	22†	Tamarack	10	17	0.85	−0.94	Upper Mattole	7.98	23 stations	0.00
Colorado	44.4	+0.7	3 stations	89	18†	Dillon	− 4	8	1.88	0.00	Las Animas	5.08	Grandlake	0.22
Florida	68.8	−1.0	3 stations	94	24†	2 stations	30	2	2.33	−0.15	Pensacola	11.72	Boca Grande	0.22
Georgia	63.9	+0.8	2 stations	93	22†	3 stations	26	1†	2.25	−1.17	Tate	5.10	Savannah	0.55
Hawaii (March)	69.2	+0.3	Mahukona	93	13	Glenwood	45	25	5.70	−2.65	Honomu	27.95	Makopuu Point	0.01
Idaho	46.4	+0.9	Glenn's Ferry	95	24	2 stations	4	9†	1.39	−0.12	Middle Fork	3.89	Buhl	T.
Illinois	53.4	+1.4	Mount Vernon	89	7	Alexander	19	1	2.50	−0.75	Ewing	4.84	Urbana	0.75
Indiana	52.1	0.0	Princeton	89	23	Auburn	12	1	3.14	−0.24	Huntingburg	5.42	Veedersburg	1.74
Iowa	48.4	−0.3	Fairfield	81	6	3 stations	20	1	4.78	+1.92	Cumberland	9.00	Kookuk	1.94
Kansas	53.2	−0.8	2 stations	89	22	2 stations	15	8†	3.93	+1.61	Leavenworth	6.60	Liberal	0.54
Kentucky	56.7	+0.8	Earlington	89	23	2 stations	19	1†	3.51	−0.43	Calhoun	5.55	Eubank	1.48
Louisiana	66.2	−1.0	Reserve	93	25	Kelly (near)	31	2	5.56	+1.30	Dutchtown	9.23	Robeline	1.84
Maryland-Delaware	51.8	−0.5	Cumberland	88	9	Oakland	11	2	3.42	+0.03	Milford, Del	4.92	Westernport	1.30
Michigan	42.7	+0.3	2 stations	80	6†	Sidnaw	3	1	3.37	+1.12	Wasepi	6.40	Victoria	1.75
Minnesota	43.3	+0.1	Warren	85	30	Winton	9	1†	2.55	+0.63	New Ulm	5.77	Grand Marais	0.36
Mississippi	63.1	−1.0	Yazoo City	92	24	Booneville	28	1	5.17	+0.18	Woodville	11.72	Rosedale	2.36
Missouri	55.3	+0.3	2 stations	94	11†	Goodland	20	1†	3.01	−0.64	Grant City	5.72	Goodland	1.48
Montana	45.2	+3.1	Chester	88	28	Babb	1	6	0.66	−0.48	Trout Creek	2.73	12 stations	0.00
Nebraska	47.4	−1.6	Lodgepole	88	18	Fort Robinson	5	8	3.12	+0.69	Plattsmouth	9.09	Kowanda	0.47
Nevada	50.7	+2.2	Las Vegas	99	30	Marlette Lake	10	14	0.44	−0.36	Gold Creek	1.91	2 stations	0.00
New England	42.9	−0.2	Franklin, N. H	84	23	Patten, Me	−13	1	2.71	−0.36	Danielson, Conn	5.52	Northfield, Vt	1.39
New Jersey	49.3	+0.3	Layton	85	7	Culvers Lake	10	2	3.06	−0.41	Tuckerton	4.79	Culvers Lake	2.20
New Mexico	51.9	+0.7	Deming	99	20	Red River Canyon	4	10	2.16	+0.98	San Jon	6.27	Lordsburg	0.02
New York	43.0	−1.1	Port Jervis	84	7	Indian Lake	− 3	3	3.23	+0.27	Adams Center	6.00	Oneonta	0.93
North Carolina	57.9	+0.3	Wenona	93	8	2 stations	16	1	2.96	−0.72	Highlands	6.66	Willard	1.01
North Dakota	43.3	+0.6	Berthold Agency	79	20	Bowbells	6	24	1.52	+0.14	Hettinger	4.23	Towner	0.55
Ohio	49.7	−0.3	2 stations	89	9	Dover	10	2†	3.02	+0.06	Montpelier	5.86	Gambier	1.81
Oklahoma	59.5	−0.4	Sallisaw	94	23	Hooker	19	10	4.07	+1.37	Hobart	7.78	Hugo	1.25
Oregon	50.0	+0.9	La Grande	89	27	Austin	6	3	2.50	+0.66	Deadwood	10.31	Rio Hermoso	0.14
Pennsylvania	48.5	−0.6	Lykens	90	8	West Bingham	6	1	2.70	−0.72	Erie	4.76	Media	0.99
Porto Rico	76.0	+0.6	Canovanas	95	1	Jayuya	54	2	7.87	+2.76	Comerio Falls	17.49	San Juan	3.09
South Carolina	62.4	+1.4	3 stations	92	14†	Saluda	24	2	2.10	−0.76	Heath Spring	4.10	Walterboro	0.36
South Dakota	44.8	−0.8	Rosebud Agency	85	18	Oelrichs	6	9	2.87	+0.69	Harveys Ranch	6.55	Lemmon	1.10
Tennessee	59.0	+0.7	Decatur	91	21†	Crossville	19	1	3.27	−1.31	Johnsonville	5.19	Sewanee	1.95
Texas	65.6	0.0	2 stations	99	6†	Dalhart	23	10	2.55	−0.48	Childress	9.40	Barstow	0.17
Utah	49.0	+1.9	St. George	93	22	Black's Fork	− 9	8	0.89	−0.39	Silver Lake	3.56	Green River	0.00
Virginia	54.7	+0.1	Lincoln	94	9	Burkes Garden	14	1	3.01	−0.24	Callaville	5.06	Norfolk	1.61
Washington	49.5	+0.9	Leahy	89	27	Lake Keechelus	12	15	2.54	+0.56	Quiniault	11.72	2 stations	T.
West Virginia	51.8	−0.1	3 stations	90	9†	Parsons	8	2	2.44	−1.12	Camden-on-Gauley	4.21	Bayard	1.03
Wisconsin	43.3	+0.1	Sheboygan	78	7	Big St. Germain Dam.	4	1	3.36	+0.95	Oconto	7.55	Cornucopia	0.60
Wyoming	41.9	+0.7	2 stations	82	5†	Foxpark	− 9	16	1.39	0.09	Elk Mountain	5.50	Powell	T.

†Other dates also.

TABLE I.—*Climatological data for Weather Bureau stations, April, 1919.*

Districts and stations.	Elevation of instruments: Barometer above sea level.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature of the air: Mean max. + mean min. ÷ 2.	Temperature of the air: Departure from normal.	Temperature of the air: Maximum.	Temperature of the air: Date.	Temperature of the air: Mean maximum.	Temperature of the air: Minimum.	Temperature of the air: Date.	Temperature of the air: Mean minimum.	Temperature of the air: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with .01, or more.	Wind: Total movement.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F	°F	°F		°F	°F		°F	°F	°F	°F	%	In.	In.		Miles.								0–10	In.	In.
New England.							43.4	− 0.2										74	2.47	− 0.6										6.7		
Eastport	76	67	85	29.89	29.97	+0.04	38.4	+ 0.1	51	12	44	19	2	33	17	36	32	79	2.15	− 0.8	14	8,113	s.	44	s.	12	4	4	22	7.4	5.2	0.0
Greenville	1,070	6		28.78	29.97		36.4		65	23	46	6	4	27	39				2.96		17						5	5	20		10.8	0.0
Portland, Me.	103	82	117	29.88	30.00	+ .04	42.3	− 0.7	63	23	49	17	2	36	25	37	31	68	2.20	− 0.9	13	6,581	nw.	30	e.	16	7	6	17	6.7	1.3	0.0
Concord	288	70	79	29.68	29.99	.00	43.3	− 0.5	71	23	53	15	1	34	40				1.92	− 0.9	12	3,268	nw.	13	nw.	21	11	7	12	5.3	0.4	0.0
Burlington	404	11	48	29.54	30.00	+ .01	39.5	− 1.2	70	23	47	12	1	32	37				2.42	+ 0.6	16	7,756	s.	46	s.	11	4	7	19	7.6	0.9	0.0
Northfield	876	12	60	29.04	30.01	+ .02	38.6	− 1.6	70	23	48	8	3	29	44	35	30	75	1.39	− 0.7	13	5,222	n.	28	s.	24	3	7	20	7.9	0.4	0.0
Boston	125	115	188	29.85	29.99	+ .02	46.8	+ 1.5	68	20	54	19	2	40	30	41	35	66	2.33	− 1.2	12	7,525	w.	36	w.	25	6	7	17	7.0	T.	0.0
Nantucket	12	14	90	29.98	29.99	+ .02	43.2	− 1.0	58	20	48	22	2	38	20	41	39	89	2.46	− 0.2	12	11,680	sw.	42	w.	25	7	7	16	7.0	T.	0.0
Block Island	26	11	46	29.96	29.99	+ .01	44.2	+ 0.4	59	12	50	20	2	38	20	42	40	91	2.49	− 1.1	12	12,780	sw.	56	w.	25	9	4	17	6.3	T.	0.0
Providence	160	215	251	29.82	30.00	+ .02	46.3	− 0.3	66	23	55	20	2	38	29	40	34	68	3.32	− 0.4	12	9,725	w.	55	w.	25	7	12	11	6.0	T.	0.0
Hartford	159	122	140	29.83	30.01	+ .02	47.4	+ 0.7	72	23	56	18	1	39	30	41	34	66	2.79	− 0.8	14	6,045	nw.	36	s.	11	8	6	16	6.6	T.	0.0
New Haven	106	117	155	29.90	30.02	+ .03	47.0	+ 0.6	66	23	55	20	2	39	26	41	34	66	3.71	+ 0.2	13	7,298	n.	32	w.	25	9	9	12	5.5	T.	0.0
Middle Atlantic States.							51.2	+ 0.5										66	2.86	− 0.2										5.7		
Albany	97	102	115	29.90	30.01	+ .01	45.3	− 0.5	73	23	54	19	1	37	35	40	35	70	1.98	− 0.4	13	5,882	nw.	33	s.	10	10	5	15	6.2	0.3	0.0
Binghamton	871	10	69	29.06	30.01	− .01	45.2	+ 0.8	79	7	55	16	1	36	40				2.22	0.0	15	4,826	nw.	34	sw.	11	6	6	18	7.1	0.9	0.0
New York	314	414	454	29.67	30.01	+ .01	48.8	+ 0.7	76	7	57	21	1	40	35	41	33	59	2.55	− 0.8	11	13,718	nw.	62	nw.	24	5	13	12	6.5	T.	0.0
Harrisburg	374	94	104	29.63	30.04	+ .02	51.0	+ 0.3	81	7	60	23	1	42	33	43	35	58	1.93	− 0.6	8	5,588	nw.	29	nw.	24	5	13	12	6.5	0.1	0.0
Philadelphia	117	123	190	29.92	30.04	+ .03	52.4	+ 1.6	77	7	62	24	1	43	33	46	40	68	3.17	+ 0.3	8	8,231	nw.	37	nw.	24	9	11	10	5.6	T.	0.0
Reading	325	81	98	29.68	30.04		51.0		83	7	61	23	1	41	34	44	39	68	2.07	− 1.2	9	6,084	nw.	40	se.	16	9	11	10	5.8	T.	0.0
Scranton	805	111	119	29.15	30.02	+ .01	47.9	+ 0.8	82	7	57	19	1	38	37	44	41	81	2.71	+ 0.1	14	5,945	sw.	34	nw.	25	7	7	16	6.4	1.3	0.0
Atlantic City	52	37	48	29.97	30.03	+ .03	48.8	+ 1.2	72	24	56	23	1	42	34	44	39	74	3.50	+ 0.5	10	6,356	nw.	28	nw.	24	12	10	8	4.9	T.	0.0
Cape May	18	13	49	30.05	30.07	+ .08	50.0	+ 1.6	72	24	57	26	1	43	33	45	41	76	4.45	+ 1.5	10	7,736	nw.	36	nw.	24	8	10	12		0.1	0.0
Sandy Hook	22	10	57	30.00	30.02		48.0		69	7	55	23	1	41	26	43	38	75	2.61		11	12,153	w.	61	s.	11	10	11	9	5.3	0.1	0.0
Trenton	190	159	183	29.81	30.02		49.9		77	7	60	21	1	40	33	43	36	64	2.91	− 0.4	9	9,572	nw.	48	w.	25	8	13	9	5.9	T.	0.0
Baltimore	123	100	113	29.91	30.04	+ .03	52.9	− 0.1	73	20	62	25	2	44	33	46	38	62	4.05	+ 0.8	6	5,320	sw.	30	nw.	24	8	13	9	5.8	T.	0.0
Washington	112	62	85	29.92	30.04	+ .02	53.8	+ 0.7	83	9	64	24	2	44	34	46	38	61	3.72	+ 0.5	8	5,769	nw.	42	nw.	24	7	11	12	6.0	T.	0.0
Lynchburg	681	153	188	29.30	30.04	+ .02	55.6	0.0	86	9	68	27	2	44	36	48	40	61	2.18	− 1.0	9	5,821	nw.	37	nw.	24	14	7	9	5.2	0.0	0.0
Norfolk	91	170	205	29.96	30.06	+ .05	56.9	+ 0.9	84	15	67	27	2	47	35	49	43	65	1.61	− 2.2	8	9,622	s.	44	sw.	16	13	9	8	4.4	T.	0.0
Richmond	144	11	52	29.89	30.05	+ .03	56.6	− 0.6	83	15	68	24	2	45	38	49	43	67	3.25	− 0.2	7	5,235	se.	24	s.	16	10	7	13	5.7	0.0	0.0
Wytheville	2,293	49	55	27.66	30.04	+ .01	51.3	− 0.3	80	9	63	20	1	40	37	44	38	63	3.45	− 0.2	9	5,338	nw.	31	s.	10	13	10	7	4.3	0.0	0.0
South Atlantic States.							61.9	+ 0.7										67	1.93	− 1.4										4.0		
Asheville	2,255	70	84	27.71	30.06	+ .03	54.4	+ 0.5	81	9	66	25	1	43	38	46	39	60	2.11	− 1.9	7	7,226	nw.	32	se.	15	14	10	6	4.0	T.	0.0
Charlotte	773	153	161	29.21	30.05	+ .02	60.0	+ 0.8	87	9	71	30	1	49	32	53	48	69	3.90	+ 0.5	7	4,176	sw.	20	nw.	24	10	12	8	4.9	0.0	0.0
Hatteras	11	12	50	30.05	30.06	+ .05	58.4	+ 0.4	77	24	65	34	2	52	25	54	50	75	1.80	− 2.6	10	9,436	sw.	50	n.	24	11	11	8	4.8	0.0	0.0
Raleigh	376	103	110	29.64	30.05	+ .02	59.8	+ 0.8	86	9	70	30	2	49	33	52	47	67	1.69	− 1.8	6	5,922	sw.	34	sw.	16	10	12	8	4.8	0.0	0.0
Wilmington	78	81	91	29.99	30.07	+ .04	61.6	+ 1.2	87	9	71	33	2	52	26	54	49	70	3.23	+ 0.4	7	5,565	sw.	32	sw.	11	18	7	5	3.6	0.0	0.0
Charleston	48	11	92	30.02	30.07	+ .04	64.4	+ 0.6	89	24	72	38	1	57	25	57	53	71	0.73	− 2.3	3	7,059	s.	33	sw.	11	20	3	7	3.2	0.0	0.0
Columbia, S. C.	351	41	57	29.69	30.07	+ .04	63.6	+ 0.8	87	29	75	32	1	52	32	53	45	58	2.14	− 0.7	5	5,011	s.	30	sw.	16	18	7	5	3.6	0.0	0.0
Augusta	180	62	77	29.86	30.05	+ .02	63.8	+ 0.6	88	29	76	34	1	52	35	56	49	63	1.92	− 1.6	4	4,172	nw.	31	sw.	16	14	8	8	4.5	0.0	0.0
Savannah	65	150	194	30.00	30.07	+ .04	65.8	+ 1.1	89	24	75	39	1	57	27	57	53	70	0.55	− 2.4	3	8,470	s.	48	s.	11	16	7	7	4.0	0.0	0.0
Jacksonville	43	200	245	30.02	30.07	+ .03	67.3	+ 0.3	87	24	75	42	2	60	23	59	54	71	1.26	− 1.5	3	8,631	se.	35	se.	11	20	5	5	3.3	0.0	0.0
Greenville, S. C.	1,013	113	122	28.94	30.03		60.8		85	24	72	32	1	50	29	51	44	59	1.80		5	6,053	sw.	33	w.	17	15	9	6	3.7	0.0	0.0
Florida Peninsula.							73.0	−0.6										70	2.20	+ 0.3										4.1		
Key West	22	10	64	30.00	30.02	.00	75.5	0.0	86	16	81	63	3	70	17	68	64	72	3.11	+ 1.8	5	7,465	e.	25	nw.	18	19	7	4	3.1	0.0	0.0
Miami	25	71	79	30.03	30.06		72.6	− 1.6	84	25	78	56	2	67	21	66	62	71	3.07	+ 0.5	8	6,881	e.	28	ne.	26	13	12	5	4.7	0.0	0.0
Tampa	35	79	92	30.02	30.06	.00	70.8	− 0.2	88	25	80	46	2	61	20	62	57	67	0.41	− 1.4	2	4,974	ne.	27	sw.	16	12	12	6	4.0	0.0	0.0
East Gulf States.							64.2	− 0.4										67	4.94	+ 0.9										3.9		
Atlanta	1,174	190	216	29.83	30.06	+ .03	61.7	+ 0.6	83	23	72	30	1	52	27	52	45	59	4.18	+ 0.6	6	8,172	nw.	33	nw.	1	17	6	7	3.7	0.0	0.0
Macon	370	78	87	29.66	30.06	+ .03	63.8	+ 0.7	87	23	76	33	1	52	37	54	45	56	1.83	− 1.6	6	4,316	nw.	21	s.	15	16	6	8	3.9	0.0	0.0
Thomasville	273	49	58	29.76	30.06	+ .03	66.4	− 0.3	88	24	78	37	1	55	32	56	49	61	2.78	− 0.9	3	3,031	n.	16	sw.	4	15	8	7	3.9	0.0	0.0
Pensacola	56	149	185	30.01	30.07	+ .05	65.0	− 2.7	87	24	71	41	1	59	21	60	57	79	11.72	+ 8.6	7	8,812	se.	50	se.	10	17	3	10	3.8	0.0	0.0
Anniston	741	9	57	29.29	30.08	+ .05	60.9	+ 0.5	85	8	74	30	2	48	38				3.97	+ 0.3	6	3,752	s.	20	se.	10	17	4	9	3.8	0.0	0.0
Birmingham	700	11	48	29.31	30.08	+ .06	62.8	− 0.7	85	8	74	32	2	52	32	52	45	58	1.55	− 2.1	5	5,025	s.	28	se.	9	19	2	9	3.7	0.0	0.0
Mobile	57	125	161	30.00	30.06	+ .04	65.6	− 0.4	89	24	74	42	1	57	25	58	53	72	6.84	+ 2.5	6	6,755	nw.	32	se.	10	16	5	9	3.8	0.0	0.0
Montgomery	223	100	112	29.82	30.07	+ .04	65.1	− 0.1	88	24	76	36	1	55	29	55	49	62	4.61	+ 0.4	8	4,515	sw.	21	w.	16	17	4	9	3.9	0.0	0.0
Corinth	469	6					61.2		86	22	73	29	2	49	37				3.74		7		s.				14	11	5		0.0	0.0
Jackson	304	5					64.0		89	24	76	36	2	52	38				5.67		7		se.				17	8	5		0.0	0.0
Meridian	375	85	93	29.66	30.05	+ .03	62.7	− 1.4	86	24	74	33	2	51	34	55	49	60	3.74	− 1.3	8	3,747	s.	27	nw.	15	17	5	8	3.9	0.0	0.0
Vicksburg	247	65	74	29.76	30.05	+ .05	64.2	− 1.0	86	24	74	37	1	54	27	58	54	76	5.21	0.0	8	5,378	se.	30	s.	9	16	5	9	4.1	0.0	0.0
New Orleans	51	76	84	29.98	30.04	+ .04	68.1	+ 0.2	86	25	76	48	1	60	22	62	59	78	7.88	+ 3.0	7	4,738	se.	24	n.	10	15	6	9	4.5	0.0	0.0
West Gulf States.							65.5	− 0.4										72	2.64	− 0.9										4.6		
Shreveport	249	77	93	29.75	30.02	+ .05	65.2	− 0.6	87	24	76	43	10	55	28	57	51	65	3.93	− 0.6	6	6,075	s.	26	w.	9	17	6	7	3.8	0.0	0.0
Bentonville	1,303	11	44	28.60	29.97	+ .01	57.9	+ 1.0	85	23	69	34	18	47	37				3.74	− 0.2	11	5,169	s.	30	sw.	9	13	7	10	4.8	0.0	0.0
Fort Smith	457	79	94	29.49	29.97	+ .01	62.0	− 0.3	86	23	73	38	10	51	36	55	50	70	2.90	− 1.0	10	7,305	e.	41	w.	9	9	14	7	5.1	0.0	0.0
Little Rock	357	139	147	29.63	30.01	+ .03	61.6	− 1.1	84	23	72	37	1	52	33	54	48	65	4.09	− 0.4	10	7,342	s.	36	se.	9	13	5	12	4.7	0.0	0.0
Brownsville	57	4	26				74.3		99	6	84	48	11	64	38				2.39		4		se.									
Corpus Christi	20	69	77	29.96	29.98	+ .03	70.5	− 0.4	85	7	76	52	11	65	30	65	63	82	0.67	− 1.1	5	9,004	se.	32	s.	2	13	8	9	5.2	0.0	0.0
Dallas	512	109	117	29.42	29.97		65.5		84	24	76	40	10	55	31				2.55		10	7,917	s.	51	nw.	4	14	10	6	4.0	0.0	0.0
Fort Worth	670	106	114	29.22	29.93	− .01	65.0	− 0.3	85	12	76	38	10	54	33	58	55	74	2.06	− 0.6	9	8,774	s.	46	nw.	4	16	8	6	3.9	0.0	0.0
Galveston	54	106	114	29.97	30.03	+ .06	68.4	− 0.3	79	30	72	53	10	64	16	64	61	79	2.17	− 1.0	6	8,729	se.	36	se.	28	12	9	9	4.8	0.0	0.0
Houston	138	111	121	29.86	30.00		69.0	− 0.6	85	24	78	49	10	60	28				1.16		7	7,144	se.	32	se.	8	12	8	10	4.5	0.0	0.0
Palestine	510	64	72	29.47	30.00	+ .04	66.2	− 0.3	85	12	77	41	10	56	30	59	55	74	1.42	− 2.8	7	5,937	s.	30	s.	6	11	9	10	5.0	0.0	0.0
Port Arthur	34	58	66	29.97	30.01		67.6		82	25	74	50	17	61	23	62	58	76	1.83		6	7,550	s.	31	s.	9	13	8	9	4.8	0.0	0.0
San Antonio	701	119	132	29.24	29.96	+ .03	68.4	− 0.6	85	7	78	45	10	58	32	60	54	70	3.60	+ 0.7	3	6,668	se.	40	se.	2	11	10	9	4.6	0.0	0.0
Taylor	582	55	63	29.39	30.00	+ .05	66.8	− 0.7	85	12	78	40	10	56	37				1.86	− 2.1	7	7,648	se.	47	se.	26	12	8	10	4.8	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, April, 1919*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Temperature of the air: Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Departure from normal.	Days with .01, or more.	Wind: Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F	°F	°F		°F	°F		°F	°F	°F	°F	%	In.	In.		Miles.								0–10	In.	In.
Ohio Valley and Tennessee.							**54.8**	**+ 0.2**										**66**	**3.02**	**− 0.6**										**6.2**		
Chattanooga	762	189	213	29.26	30.07	+0.04	60.2	+ 0.2	84	9	71	32	1	50	32	51	43	58	2.90	− 1.5	8	5,853	s.	33	s.	10	13	10	7	4.6	0.0	0.0
Knoxville	996	102	111	28.99	30.05	+ .02	58.6	+ 1.2	86	9	70	30	1	47	36	51	44	65	3.68	− 1.0	10	4,632	sw.	26	sw.	15	9	13	8	5.2	0.0	0.0
Memphis	399	76	97	29.64	30.06	+ .06	61.7	− 0.1	82	14	70	35	1	53	22	54	47	63	3.17	− 1.7	8	6,807	s.	36	sw.	10	14	8	8	4.9	0.0	0.0
Nashville	546	168	191	29.47	30.06	+ .05	59.2	+ 0.1	84	23	69	28	1	49	29	50	43	60	2.66	− 1.7	8	6,426	se.	40	sw.	15	13	6	11	5.1	T.	0.0
Lexington	989	193	230	28.98	30.06	+ .04	54.3	+ 0.6	84	9	64	24	1	45	32	......	......	......	3.51	+ 0.2	14	10,059	sw.	42	sw.	10	9	8	13	5.8	0.0	0.0
Louisville	525	219	255	29.46	30.05	+ .04	56.6	+ 0.4	84	9	66	25	1	47	34	49	43	64	3.15	− 0.9	11	9,207	s.	44	s.	10	11	5	14	5.7	0.0	0.0
Evansville	431	139	175	29.56	30.03	+ .03	57.6	+ 1.2	83	23	67	27	1	48	30	51	45	65	3.71	+ 0.2	13	8,908	sw.	46	sw.	10	6	16	8	6.2	0.0	0.0
Indianapolis	822	194	230	29.12	30.02	+ .02	52.2	− 0.2	81	9	61	25	1	44	28	46	40	69	3.35	− 0.1	11	9,264	s.	38	sw.	10	6	11	13	6.6	T.	0.0
Terre Haute	575	96	129	29.38	30.00	......	54.2	......	80	9	63	26	1	45	26	48	44	74	2.98	......	14	7,669	s.	34	se.	14	2	17	11	6.5	0.0	0.0
Cincinnati	628	11	51	29.35	30.04	+ .03	52.6	+ 0.3	84	9	63	25	1	42	32	46	40	66	3.29	+ 0.3	12	6,016	sw.	34	se.	10	7	8	15	6.6	T.	0.0
Columbus	824	173	222	29.15	30.04	+ .02	50.8	− 0.2	81	9	60	21	1	42	29	45	41	74	2.26	− 0.6	11	8,797	nw.	49	w.	23	4	8	18	7.1	T.	0.0
Dayton	899	181	216	29.03	30.00	......	51.4	− 0.3	82	9	61	22	1	42	29	45	40	70	3.57	+ 0.7	11	8,205	sw.	46	s.	10	7	8	15	6.6	0.0	0.0
Pittsburgh	842	353	410	29.12	30.04	+ .02	51.0	0.0	80	9	60	19	2	42	30	43	37	66	3.07	+ 0.2	14	8,445	sw.	39	nw.	25	2	5	23	8.1	0.5	0.0
Elkins	1,940	41	50	27.98	30.05	+ .02	48.4	− 0.3	80	9	60	16	2	36	43	42	37	69	1.94	− 1.4	13	3,825	w.	27	w.	16	2	8	20	7.5	0.4	0.0
Parkersburg	638	77	84	29.39	30.05	+ .02	52.9	− 0.1	84	9	64	21	2	42	35	45	39	65	2.09	− 0.8	11	4,492	se.	30	nw.	23	7	8	15	6.8	T.	0.0
Lower Lake Region.							**44.6**	**− 0.6**										**73**	**3.84**	**+ 1.5**										**7.0**		
Buffalo	767	247	280	29.16	30.01	.00	42.5	+ 0.2	75	23	50	11	1	35	32	38	34	78	3.40	+ 1.0	17	12,091	sw.	52	w.	25	7	4	19	7.3	2.8	0.0
Canton	448	10	61	29.48	29.97	......	39.3	− 3.2	69	23	47	7	1	31	36	......	......	......	3.39	+ 1.1	15	7,541	sw.	38	w.	20	8	4	18	6.7	2.2	0.0
Oswego	335	76	91	29.62	30.00	− .01	41.4	− 1.8	70	23	48	11	1	34	37	38	34	76	3.20	+ 0.9	14	7,770	w.	39	nw.	24	5	6	19	7.3	1.1	0.0
Rochester	523	97	113	29.44	30.03	+ .02	43.5	− 0.4	76	23	51	15	1	36	35	38	33	70	2.99	+ 0.6	17	6,717	w.	29	nw.	25	6	4	20	7.6	4.2	0.0
Syracuse	597	97	113	29.35	30.00	− .01	43.1	− 1.3	72	23	51	12	1	35	37	......	......	......	3.80	+ 1.5	16	8,246	nw.	46	s.	11	4	8	18	7.1	9.7	0.0
Erie	714	130	166	29.23	30.01	− .01	44.7	0.0	74	7	52	18	1	37	32	40	35	71	4.76	+ 2.4	18	9,848	sw.	52	se.	16	3	11	16	6.8	1.1	0.0
Cleveland	762	190	201	29.19	30.02	.00	47.0	+ 1.0	74	9	55	23	1	39	35	43	37	69	2.96	+ 0.6	15	9,902	nw.	45	s.	10	7	8	15	6.9	T.	0.0
Sandusky	629	62	103	29.33	30.02	.00	46.8	− 0.5	77	7	54	24	1	39	34	......	......	......	3.41	+ 0.9	14	9,960	sw.	58	sw.	10	4	12	14	7.6	T.	0.0
Toledo	628	208	243	29.33	30.02	+ .01	47.0	− 0.3	76	8	56	20	1	39	34	42	37	72	5.15	+ 2.9	14	10,653	sw.	52	s.	10	8	9	13	6.4	T.	0.0
Fort Wayne	856	113	124	29.09	30.02	......	48.6	− 0.7	80	9	57	19	1	40	30	43	38	70	2.54	......	11	7,841	sw.	36	sw.	9	6	11	13	6.4	0.0	0.0
Detroit	730	218	245	29.21	30.02	.00	46.0	+ 0.5	73	8	54	21	1	37	30	42	39	80	5.29	+ 3.0	13	8,814	sw.	40	sw.	11	5	13	12	6.6	T.	0.0
Upper Lake Region.							**41.9**	**+ 1.1**										**76**	**2.90**	**+ 0.6**										**6.5**		
Alpena	609	13	92	29.34	30.02	.00	38.8	+ 0.8	70	6	45	13	1	32	28	36	31	75	2.03	− 0.2	16	9,841	nw.	52	ne.	16	5	10	15	6.8	T.	0.0
Escanaba	612	54	60	29.35	30.03	+ .01	38.2	+ 1.0	59	6	44	12	1	32	25	35	31	80	2.68	+ 0.6	13	7,794	s.	36	n.	16	13	5	12	5.0	T.	0.0
Grand Haven	632	54	92	29.31	30.00	− .01	43.7	− 0.3	66	10	51	20	1	36	27	40	36	76	2.40	0.0	17	9,668	e.	43	n.	23	5	12	13	6.9	0.6	0.0
Grand Rapids	707	70	87	29.24	30.02	.00	45.6	− 0.6	71	6	54	20	1	37	28	40	34	68	2.60	+ 0.2	15	5,517	nw.	27	nw.	24	8	8	14	6.4	5.0	0.0
Houghton	684	62	99	29.28	30.02	.00	38.4	+ 1.5	69	21	46	16	1	31	41	......	......	......	1.76	− 0.3	11	8,048	e.	46	e.	7	10	6	14	6.3	0.9	0.0
Lansing	878	11	62	29.05	30.01	......	44.8	− 0.8	73	8	54	17	1	35	30	40	36	75	4.13	+ 1.6	15	5,524	sw.	25	s.	10	6	6	18	7.0	3.2	0.0
Ludington	637	60	66	29.29	30.00	......	42.0	......	64	10	48	22	1	36	25	39	36	82	2.94	......	16	8,527	s.	38	s.	5	6	9	15	6.5	4.9	0.0
Marquette	734	77	111	29.24	30.06	+ .04	39.2	+ 1.7	66	22	46	23	1	33	32	35	30	72	3.24	+ 1.2	10	7,637	nw.	32	nw.	24	4	11	15	7.5	0.2	0.0
Port Huron	638	70	120	29.30	30.00	− .02	43.4	+ 1.2	69	6	51	20	1	36	28	39	36	80	3.94	+ 1.9	11	8,679	sw.	41	nw.	25	4	13	13	6.4	T.	0.0
Saginaw	641	48	82	29.30	30.00	......	44.2	......	72	6	53	16	1	35	28	40	35	75	2.31	− 0.4	12	8,022	nw.	36	s.	10	7	5	18	6.8	0.4	0.0
Sault Sainte Marie	614	11	61	29.32	30.03	.00	38.0	+ 2.3	67	22	46	6	1	30	39	34	29	75	4.87	+ 2.8	13	7,597	nw.	48	nw.	25	11	7	12	6.0	0.8	0.0
Chicago	823	140	310	29.11	30.00	.00	48.0	+ 2.1	75	6	55	28	1	41	30	44	40	76	3.16	+ 0.3	16	9,402	s.	42	sw.	10	3	12	15	7.0	T.	0.0
Green Bay	617	109	144	29.32	29.98	− .03	43.5	+ 2.8	69	19	52	19	1	35	31	39	34	72	3.20	+ 0.8	14	9,333	ne.	60	ne.	7	7	7	16	6.6	T.	0.0
Milwaukee	681	119	133	29.24	29.99	.00	44.2	+ 2.4	71	6	51	20	1	37	29	40	36	77	2.49	− 0.2	15	7,794	ne.	48	se.	7	8	6	16	6.7	T.	0.0
Duluth	1,133	11	47	28.78	30.02	+ .01	39.2	+ 0.8	70	22	46	18	1	32	29	35	30	74	1.82	− 0.3	12	9,785	ne.	57	ne.	7	9	6	15	6.1	0.1	0.0
North Dakota.							**42.9**	**+ 2.2**										**70**	**1.51**	**− 0.4**										**5.6**		
Moorhead	940	8	57	28.98	30.01	+ .02	44.2	+ 2.8	75	22	54	20	24	34	35	38	33	74	2.06	− 0.3	8	7,565	se.	34	w.	5	12	8	10	5.0	3.1	0.0
Bismarck	1,674	8	57	28.21	30.02	+ .05	43.4	+ 0.8	76	18	53	19	24	33	36	38	31	68	1.71	− 0.2	8	8,366	nw.	48	w.	5	8	8	14	5.9	12.7	0.0
Devils Lake	1,482	11	44	28.40	30.00	+ .01	40.5	+ 2.3	72	18	49	18	24	32	33	36	31	74	1.14	− 0.9	5	8,915	ne.	48	ne.	7	8	11	11	6.0	3.6	0.0
Ellendale	1,457	10	56	28.41	29.99	......	42.8	......	74	21	52	19	24	34	34	38	34	76	2.23	......	10	11,612	ne.	54	w.	5	8	8	14	6.4	10.1	0.0
Grand Forks	835	12	89	......	......	......	42.6	......	72	21	52	19	24	33	35	38	......	......	1.73	......	6	......	n.	37	w.	6	14	11	5	......	8.1	0.0
Williston	1,872	41	48	27.97	29.97	+ .01	43.6	+ 3.1	75	20	54	21	10	33	37	37	30	64	1.12	− 0.1	9	7,132	se.	44	ne.	22	6	14	10	5.7	2.4	0.0
Upper Mississippi Valley.							**51.0**	**+ 0.5**										**70**	**3.21**	**+ 0.3**										**6.6**		
Minneapolis	918	10	208	28.96	29.96	......	45.2	......	74	22	53	27	24	37	34	......	......	......	3.44	+ 1.0	14	8,981	n.	42	n.	10	8	6	16	6.7	2.2	0.0
St. Paul	837	201	236	29.06	29.98	− .01	45.5	− 0.2	72	22	54	26	1	37	31	......	......	......	3.98	+ 1.6	16	8,950	se.	46	e.	7	7	10	13	6.3	5.6	0.0
La Crosse	714	11	48	29.19	29.98	.00	46.8	− 0.5	75	22	55	25	1	38	32	......	......	......	3.41	+ 1.1	15	4,260	s.	20	s.	5	5	8	17	7.1	0.6	0.0
Madison	974	70	78	28.94	30.00	+ .01	45.8	+ 1.3	71	19	54	23	1	38	28	40	36	73	2.90	+ 0.5	15	7,420	se.	34	s.	5	3	5	22	8.1	T.	0.0
Wausau	1,247	4	......	28.63	29.98	......	42.6	......	71	22	51	16	1	34	34	......	......	......	3.07	......	11	......	se.	......	......	......	11	3	16	6.4	0.8	0.0
Charles City	1,015	10	49	28.89	29.98	.00	46.1	− 0.2	73	22	55	24	1	37	39	42	38	76	3.29	+ 0.5	16	5,558	ne.	25	n.	23	4	12	14	6.7	T.	0.0
Davenport	606	71	79	29.31	29.97	− .01	51.0	+ 0.8	77	6	60	30	1	42	28	45	40	72	3.60	+ 0.7	17	6,509	e.	28	e.	14	3	12	15	6.8	0.0	0.0
Des Moines	861	84	97	29.05	29.97	.00	49.3	− 1.3	76	6	57	31	1	41	29	45	41	76	5.30	+ 2.3	15	6,204	e.	40	sw.	7	5	12	13	6.9	0.9	0.0
Dubuque	698	81	96	29.24	29.99	+ .01	49.0	+ 0.1	75	6	57	28	1	41	29	43	38	70	4.47	+ 1.6	15	5,217	s.	29	sw.	19	7	8	15	6.6	0.1	0.0
Keokuk	614	64	78	29.30	29.98	.00	52.9	+ 0.9	77	6	62	31	1	44	31	46	41	69	1.94	− 1.4	15	6,578	ne.	36	sw.	10	6	12	12	6.0	T.	0.0
Cairo	356	87	93	29.62	30.00	+ .01	59.6	+ 1.3	84	23	68	31	1	51	22	51	45	64	4.78	+ 1.2	11	6,673	s.	38	s.	14	3	12	15	7.0	0.0	0.0
Peoria	609	11	45	29.32	29.99	.00	51.3	+ 0.4	76	6	61	23	1	42	30	46	41	74	2.35	− 0.9	14	5,922	s.	30	e.	14	8	10	12	6.2	0.0	0.0
Springfield, Ill.	644	10	91	29.29	29.97	− .01	54.0	+ 2.0	79	23	64	27	1	44	32	47	42	70	1.26	− 2.0	10	7,071	s.	34	s.	10	5	9	16	6.9	T.	0.0
Hannibal	534	74	109	29.40	29.97	− .01	53.8	+ 0.2	81	6	64	28	1	44	32	......	......	......	2.44	− 0.8	12	7,729	sw.	40	sw.	10	8	10	12	6.0	T.	0.0
St. Louis	567	265	303	29.37	29.98	.00	57.5	+ 1.4	82	22	67	32	1	48	31	49	42	61	1.76	− 1.8	11	10,833	s.	50	s.	7	10	12	8	5.0	T.	0.0
Missouri Valley.							**50.3**	**−0.2**										**71**	**3.30**	**+0.4**										**6.4**		
Columbia, Mo.	781	11	84	29.13	29.97	− .01	55.0	+0.7	82	22	65	27	1	45	36	......	......	......	2.84	−0.9	12	6,881	se.	39	nw.	21	7	11	12	5.9	T.	0.0
Kansas City	963	161	181	28.92	29.96	.00	54.4	−0.1	85	22	63	34	1	46	35	48	42	68	3.49	+0.2	10	9,813	s.	40	nw.	16	11	9	10	5.6	T.	0.0
St. Joseph	967	11	49	28.91	29.95	......	53.2	......	83	22	62	33	1	44	32	46	40	68	3.55	......	9	8,003	nw.	38	nw.	23	9	10	11	5.7	T.	0.0
Springfield, Mo.	1,324	98	104	28.57	29.98	+ .01	56.4	+0.7	84	22	66	30	1	47	33	49	42	64	3.55	−0.3	11	8,779	s.	10	s.	9	17	8	5	3.7	0.0	0.0
Iola	984	11	50	28.90	29.95	.00	55.8	+1.6	86	22	66	32	11	46	37	......	......	......	4.37	+1.6	10	6,535	s.	31	s.	19	5	15	10	6.1	T.	0.0
Topeka	983	85	101	......	......	......	53.4	−0.3	86	22	63	32	1	44	34	......	......	......	4.09	+1.4	11	8,968	s.	37	sw.	19	7	12	11	5.8	T.	0.0
Drexel	1,299	10	54	28.52	29.92	......	47.2	......	73	18	56	28	24	39	36	43	39	76	4.53	......	17	9,633	nw.	70	w.	22	2	11	17	7.5	0.6	0.0
Lincoln	1,189	11	84	28.67	29.94	.00	49.5	−1.2	79	22	58	30	24	41	34	44	39	72	3.39	+0.6	15	8,450	nw.	43	nw.	2	4	7	19	7.5	0.6	0.0
Omaha	1,105	115	122	28.76	29.96	+ .01	49.1	−1.4	73	6	57	29	24	42	28	45	42	78	4.66	+1.6	17	7,230	nw.	42	nw.	22	4	9	17	7.2	0.3	0.0
Valentine	2,598	47	54	27.23	29.97	+ .03	44.7	−0.7	85	18	54	23	10	35	39	39	33	71	1.67	−0.6	10	9,119	nw.	38	nw.	7	5	12	13	6.6	1.6	0.0
Sioux City	1,135	94	164	28.74	29.97	+ .02	47.4	−1.1	73	22	55	26	24	40	30	42	37	74	3.02	+0.2	13	10,279	n.	45	nw.	5	3	6	21	7.8	5.9	0.0
Huron	1,306	59	74	28.58	30.00	+ .04	45.0	−1.5	73	18	54	23	24	36	35	40	35	72	2.47	−0.2	12	9,520	se.	44	e.	7	8	7	15	6.4	4.5	0.0
Pierre	1,572	70	75	28.30	29.98	+ .03	46.2	+1.6	79	18	56	23	24	37	41	40	34	69	2.98	+1.0	9	8,220	nw.	58	nw.	5	8	7	15	6.2	6.3	0.0
Yankton	1,233	49	57	28.63	29.96	+ .01	46.3	−1.1	72	18	54	25	24	38	31	......	......	......	3.02	+0.2	13	7,172	nw.	36	s.	18	3	9	18	7.7	5.5	0.0

TABLE I.—*Climatological data for Weather Bureau stations, April, 1919*—**Continued.**

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with .01, or more.	Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Maximum velocity: Direction.	Maximum velocity: Date.						
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles									0-10	In.	In.
Northern Slope.							45.3	+2.5										60	1.17	−0.4										5.3		
Billings	3,140	5					48.6	.....	81	28	65	18	16	33	53				0.17	.....	6	.....	ne.				10	18	2	....	T.	0.0
Havre	2,505	11	44	27.31	29.96	+0.03	47.2	+4.5	78	28	59	21	9	35	40	39	32	64	0.29	−0.7	5	6,562	e.	48	n.	29	13	12	5	4.3	0.7	0.0
Helena	4,110	87	114	25.77	29.97	.00	47.3	+5.3	72	24	58	24	9	36	38	36	23	42	0.01	−1.1	1	6,425	sw.	36	sw.	11	6	13	11	6.1	T.	0.0
Kalispell	2,962	11	34	26.89	29.95	− .01	46.4	+3.9	76	24	59	27	9	34	35	38	27	53	0.24	−0.8	4	4,794	nw.	40	nw.	4	13	11	6	4.6	T.	0.0
Miles City	2,371	26	48	27.44	30.01	+ .05	49.1	+4.4	76	28	60	26	8	38	40	41	34	65	1.03	−0.2	7	5,912	n.	36	ne.	5	8	18	4	5.1	2.6	0.0
Rapid City	3,259	50	58	26.58	30.02	+ .07	44.0	+0.5	76	18	54	18	9	34	37	37	30	61	3.16	+0.9	9	8,733	n.	38	n.	7	8	10	12	6.2	16.6	0.0
Cheyenne	6,088	84	101	23.94	29.94	+ .03	41.7	+0.1	73	18	52	16	8	31	35	34	28	65	1.23	−0.6	8	11,238	n.	54	w.	13	4	19	7	5.9	7.0	0.0
Lander	5,372	60	68	24.60	29.98	+ .04	44.8	+2.6	72	18	57	21	12	32	43	36	26	58	0.93	−1.5	6	4,500	w.	40	w.	11	9	13	8	5.4	2.3	0.0
Sheridan	3,790	10	47	26.07	29.99	.....	45.2	.....	72	17	58	21	10	32	47	38	30	61	1.16	.....	10	5,447	nw.	38	nw.	4	14	7	9	4.5	1.0	0.0
Yellowstone Park	6,200	11	48	23.84	29.99	+ .03	39.4	+2.4	69	24	51	15	16	28	38	32	24	59	1.41	0.0	8	5,547	nw.	40	s.	4	8	14	8	5.3	7.8	0.0
North Platte	2,821	11	51	27.05	29.99	+ .07	47.5	−1.5	84	18	58	24	10	37	42	41	36	72	2.21	+0.1	10	7,137	n.	42	ne.	6	9	10	11	5.8	3.2	0.0
Middle Slope.							52.8	−1.0										68	3.30	−1.1										6.2		
Denver	5,292	106	113	24.66	29.91	+ .01	49.1	+1.4	81	18	61	24	9	38	38	39	30	55	2.18	0.0	8	6,203	ne.	40	n.	6	1	17	12	6.8	0.8	0.0
Pueblo	4,685	80	86	25.23	29.91	+ .03	50.6	+0.1	86	18	63	24	10	38	44	42	34	63	2.33	+0.9	10	5,429	e.	50	w.	6	7	10	13	6.1	4.4	0.0
Concordia	1,392	50	58	28.48	29.96	+ .03	51.0	−2.6	82	21	60	30	10	42	33	45	41	73	4.20	+1.8	11	7,515	nw.	36	sw.	7	4	11	15	7.1	0.6	0.0
Dodge City	2,509	11	51	27.32	29.92	+ .02	52.6	−1.8	85	21	64	25	10	41	35	46	41	74	1.65	−0.2	7	9,410	se.	48	ne.	9	7	12	11	5.7	7.6	0.0
Wichita	1,358	139	158	28.50	29.94	+ .01	54.4	−2.2	81	22	64	31	9	45	34	49	44	73	4.40	+1.7	10	11,223	s.	52	w.	7	7	13	10	6.3	0.0	0.0
Altus	1,410	5	.....				60.0	.....	85	23	72	32	10	48	43				6.36	.....	7	.....	s.				18	3	9	....	0.0	0.0
Muskogee	652	4	.....				61.6	.....	87	23	73	35	10	50	41				2.78	.....	10	.....	e.				14	8	8	....	0.0	0.0
Oklahoma	1,214	10	47	28.67	29.95	+ .03	58.8	−0.8	83	23	69	33	10	48	33	51	46	69	5.04	+2.2	9	11,062	s.	58	w.	9	12	8	10	5.3	0.0	0.0
Southern Slope.							61.6	−0.8										63	2.86	+1.2										4.0		
Abilene	1,738	10	52	28.13	29.92	+ .02	63.5	−0.9	90	12	75	35	10	52	38	51	48	63	2.75	+0.5	6	8,049	s.	42	sw.	8	15	8	7	4.0	0.0	0.0
Amarillo	3,676	10	49	26.21	29.92	+ .05	54.5	−0.1	88	21	66	26	10	43	36	46	41	69	2.56	+0.8	9	8,417	sw.	44	n.	8	10	14	6	5.1	7.6	0.0
Del Rio	944	64	71	28.94	29.92	+ .03	69.0	−1.0	90	28	80	44	10	58	34				2.43	+0.5	5	8,401	se.	39	nw.	29	15	10	5	3.6	0.0	0.0
Roswell	3,566	75	85	26.28	29.86	+ .01	59.3	−1.3	96	19	74	29	8	45	42	48	39	56	3.70	+3.2	8	6,375	s.	46	nw.	8	19	7	4	3.5	T.	0.0
Southern Plateau.							59.7	+1.9										40	0.56	+0.2										3.3		
El Paso	3,762	110	133	26.10	29.81	− .02	65.0	+1.2	92	21	78	39	9	52	35	47	28	33	0.65	+0.4	3	8,692	nw.	54	w.	6	19	8	3	2.8	0.0	0.0
Santa Fe	7,013	57	66	23.19	29.86	+ .02	48.0	+0.4	74	22	58	24	9	38	29	39	30	59	1.94	+1.1	11	5,833	sw.	37	sw.	6	6	17	7	5.7	6.0	0.0
Flagstaff	6,908	8	57	23.30	29.85	+ .01	44.5	+2.3	73	22	60	20	16	29	47	34	.....	.....	0.37	.....	6	.....	w.	39	w.	6	21	9	0	....	0.5	0.0
Phoenix	1,108	76	81	28.70	29.84	− .03	69.2	+2.6	97	23	86	42	10	53	48	52	36	37	0.17	−0.3	2	3,975	e.	29	w.	8	17	11	2	3.3	0.0	0.0
Yuma	141	9	54	29.69	29.84	− .05	72.6	+2.5	99	30	90	47	10	56	46	54	39	40	T.	−0.1	0	3,815	w.	24	n.	1	28	1	1	0.8	0.0	0.0
Independence	3,910	11	42	25.92	29.93	+ .03	59.0	+2.3	86	30	74	33	8	44	40	43	24	30	0.02	−0.1	1	5,911	nw.	60	nw.	13	11	18	1	4.0	0.0	0.0
Needles	488	4	.....	29.32	29.83	.....	72.1	.....	102	22	90	43	10	54	52	.....	.....	.....	T.	.....	0	.....	.....	.....	.....	.....	14	7	9	....	0.0	0.0
Middle Plateau.							50.7	+1.8										47	0.69	−0.5										4.9		
Reno	4,532	74	81	25.45	29.97	.00	49.4	+2.1	80	29	63	26	9	36	39	39	28	50	0.25	−0.4	6	5,799	w.	48	w.	5	10	9	11	5.1	0.7	0.0
Tonopah	6,090	12	20	24.01	29.88	.....	49.8	.....	74	30	61	25	14	39	30	37	22	37	0.03	−1.7	2	6,834	nw.	53	w.	5	18	12	0	2.8	T.	0.0
Winnemucca	4,344	18	56	25.59	29.98	+ .02	48.8	+1.7	82	23	64	18	14	33	45	38	28	53	0.49	−0.4	5	5,206	ne.	42	sw.	5	10	9	11	5.9	T.	0.0
Modena	5,479	10	43	24.55	29.88	.00	49.0	+2.1	78	22	65	24	15	33	45	36	19	38	0.27	−0.5	1	8,274	w.	57	sw.	13	13	13	4	4.3	T.	0.0
Salt Lake City	4,360	163	203	25.57	29.93	+ .01	52.1	+2.0	83	23	62	31	7	42	33	43	36	60	2.50	+0.2	7	5,262	nw.	50	nw.	5	9	10	11	5.6	3.9	0.0
Grand Junction	4,602	82	96	25.31	29.87	− .01	54.4	+1.2	84	23	66	30	10	42	34	42	28	43	0.61	−0.2	5	4,920	se.	38	se.	23	10	10	10	5.6	0.2	0.0
Northern Plateau.							50.8	+1.8										55	1.16	−0.2										5.9		
Baker	3,471	48	53	26.43	30.02	+ .02	46.6	+3.1	77	23	60	23	12	34	41	39	29	58	0.67	−0.3	6	4,916	se.	25	s.	17	10	9	11	5.4	T.	0.0
Boise	2,739	78	86	27.15	30.01	+ .03	51.8	+1.7	83	24	64	29	8	40	35	42	32	51	1.18	0.0	9	4,225	nw.	26	nw.	4	8	12	10	5.5	0.0	0.0
Lewiston	757	40	48	29.22	30.04	+ .05	54.0	+1.1	83	23	66	31	12	42	44	.....	.....	.....	1.25	+0.1	9	2,882	e.	33	w.	10	3	16	11	6.8	0.0	0.0
Pocatello	4,477	60	68	25.43	29.95	+ .01	48.2	+1.4	78	23	59	27	15	37	34	39	29	55	1.31	−0.7	10	6,796	se.	36	sw.	13	7	11	12	6.1	5.0	0.0
Spokane	1,929	101	110	27.96	30.02	+ .03	50.1	+2.4	75	27	61	30	8	39	33	41	31	55	0.93	−0.4	9	5,296	sw.	36	sw.	4	3	13	14	6.7	0.0	0.0
Walla Walla	991	57	65	28.95	30.03	+ .02	54.0	+1.2	78	27	64	33	15	44	31	45	36	54	1.62	−0.1	10	3,889	s.	34	sw.	19	11	11	8	5.3	0.0	0.0
North Pacific Coast Region.							50.2	+1.2										77	3.64	+0.4										6.4		
North Head	211	11	56	29.86	30.09	+ .04	47.5	0.0	65	15	51	40	14	44	19	46	44	89	3.71	+0.5	17	13,399	nw.	62	se.	9	3	11	16	7.2	0.0	0.0
North Yakima	1,071	4	.....				53.5	.....	83	27	68	26	11	39	39	.....	.....	.....	0.38	.....	2	.....	nw.	.....	.....	.....	13	9	8	....	0.0	0.0
Port Angeles	29	8	53	30.04	30.07	.....	46.4	.....	64	23	54	31	15	38	27	.....	.....	.....	2.67	+0.7	15	4,565	s.	28	nw.	13	5	15	10	6.0	0.0	0.0
Seattle	125	215	250	29.96	30.09	+ 0.6	49.6	+0.2	70	23	57	34	8	43	27	45	41	75	3.20	+0.5	13	6,907	n.	50	sw.	19	2	12	16	7.3	0.0	0.0
Tacoma	213	113	120	29.85	30.08	+ 0.5	50.0	+1.1	73	23	58	32	12	42	32	46	43	78	3.61	+0.8	15	4,671	sw.	32	sw.	19	3	15	12	6.6	0.0	0.0
Tatoosh Island	86	7	57	29.95	30.05	+ 0.5	47.5	+1.4	57	15	52	39	4	43	16	45	42	83	6.15	−0.2	19	11,522	w.	54	s.	19	4	14	12	6.7	0.2	0.0
Medford	1,425	4	.....				52.6	.....	83	29	67	27	8	38	45	.....	.....	.....	1.15	.....	7	.....	nw.	.....	.....	.....	8	13	9	5.0	0.0	0.0
Portland, Oreg	153	68	106	29.91	30.07	+ .01	53.4	+2.2	75	30	62	34	8	45	31	48	43	70	3.60	+0.6	16	4,478	nw.	33	w.	19	3	14	13	6.7	0.0	0.0
Roseburg	510	9	57	29.54	30.09	+ .02	53.0	+2.1	79	30	65	34	8	41	37	46	39	66	2.53	0.0	12	2,593	n.	30	w.	19	9	19	2	4.6	0.0	0.0
Middle Pacific Coast Region.							55.0	+1.4										69	0.82	−1.3										4.7		
Eureka	62	73	89	30.06	30.13	+ .02	50.5	+1.0	64	16	56	36	14	45	21	48	46	87	4.03	+0.1	12	6,304	n.	38	sw.	5	6	10	14	6.4	0.0	0.0
Mount Tamalpais	2,375	11	18	27.57	30.05	.00	52.2	+2.7	77	30	59	35	13	45	23	44	37	63	0.35	−1.1	5	11,011	nw.	68	nw.	6	12	13	5	4.4	0.0	0.0
Point Reyes Light	490	7	18	29.51	30.03	.....	50.2	+1.6	60	15	54	45	7	47	13	.....	.....	.....	0.60	.....	7	15,383	nw.	65	nw.	5	5	13	12	6.6	0.0	0.0
Red Bluff	332	50	56	29.64	30.00	− .03	61.0	+1.9	89	30	73	38	6	49	36	51	41	55	0.25	−1.6	4	4,521	se.	32	se.	5	21	8	1	2.5	0.0	0.0
Sacramento	69	106	117	29.95	30.02	+ .01	58.8	+0.8	86	29	71	40	6	47	36	51	43	61	0.11	−1.9	4	6,099	s.	33	nw.	8	17	10	3	3.2	0.0	0.0
San Francisco	155	209	213	29.89	30.06	+ .01	56.0	+2.3	70	15	63	47	7	49	22	50	46	77	0.10	−1.7	3	6,668	sw.	30	sw.	1	6	18	6	4.8	0.0	0.0
San Jose	141	12	110	29.91	30.06	.....	56.5	−0.2	78	15	69	36	14	44	36	.....	.....	.....	0.06	−1.4	1	4,525	nw.	29	nw.	5	12	10	8	4.7	0.0	0.0
South Pacific Coast Region.							59.8	+1.3										71	0.16	−0.8										4.1		
Fresno	327	89	98	29.65	30.01	+ .02	62.4	+1.2	93	30	76	40	6	49	36	51	41	56	0.06	−0.6	1	5,979	nw.	34	nw.	5	16	13	1	3.4	0.0	0.0
Los Angeles	338	159	191	29.61	29.98	− .01	60.9	+1.5	82	15	70	48	1	52	26	53	49	73	0.17	−1.0	1	4,255	ne.	24	w.	6	11	13	6	4.3	0.0	0.0
San Diego	87	62	70	29.90	29.99	.00	59.2	+1.0	76	15	65	49	8	53	22	55	52	81	0.30	−0.4	2	4,445	w.	20	nw.	17	13	12	5	4.4	0.0	0.0
San Luis Obispo	201	32	40	29.83	30.05	.00	56.7	+1.5	80	1	67	39	25	46	33	49	45	75	0.09	−1.4	3	3,537	nw.	21	ne.	14	11	12	4	4.2	0.0	0.0
West Indies.																																
San Juan, P. R	82	8	54	29.88	29.97	− .01	76.4	.....	88	1	80	69	14	73	18	.....	.....	.....	3.09	−0.8	13	10,150	ne.	33	ne.	21	9	14	7	5.4	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	29.71	29.83	− .02	81.6	+0.2	93	3	88	72	6	75	18	75	74	80	6.43	+3.3	15	6,537	nw.	31	nw.	26	0	18	12	7.2	0.0	0.0
Colon	36	30	97	29.81	29.85	− .02	80.0	−0.5	86	18	83	73	26	77	9	77	76	86	10.95	+6.6	23	8,839	n.	27	w.	26	1	7	22	8.3	0.0	0.0
Alaska.																																
Juneau	80	11	49	.....	.....	.....	42.4	.....	57	12	49	29	15	36	24	38	35	79	6.50	.....	25	3,277	se.	19	se.	19	3	3	24	8.4	T.	0.0

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during April, 1919, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex	8	9:00 p.m.	D.N.p.m.	0.66	9:09 p.m.	9:22 p.m.	0.01	0.033	0.46	0.51											
Albany, N. Y	11–12			0.92														(*)			
Alpena, Mich	10			0.47														0.31			
Amarillo, Tex	25			0.60														0.32			
Anniston, Ala	15	4:09 p.m.	9:30 p.m.	1.11	4:58 p.m.	5:23 p.m.	0.10	0.17	0.44	0.67	0.72	0.80									
Asheville, N. C	29			0.63														0.34			
Atlanta, Ga	29	1:30 p.m.	2:20 p.m.	1.48	1:51 p.m.	2:14 p.m.	0.01	0.21	0.77	1.14	1.44	1.47									
Atlantic City, N. J	16			1.58														0.47			
Augusta, Ga	11			0.97														0.45			
Baker, Oreg	13			0.22														(*)			
Baltimore, Md	16	2:05 p.m.	3:40 p.m.	1.05	2:41 p.m.	3:10 p.m.	0.07	0.09	0.32	0.63	0.75	0.81	0.91								
Bentonville, Ark	9			0.61														0.53			
Binghampton, N. Y	8			0.42														0.28			
Birmingham, Ala	15			0.61														0.34			
Bismarck, N. Dak	7			0.80														(*)			
Block Island, R. I	12			0.46														0.39			
Boise, Idaho	13			0.37														0.12			
Boston, Mass	16–17			1.60														0.40			
Buffalo, N. Y	16			0.78														0.23			
Burlington, Vt	11			1.31														0.49			
Cairo, Ill	8	D.N.a.m.	6:15 a.m.	1.11	4:13 a.m.	4:52 a.m.	0.44	0.19	0.25	0.31	0.33	0.44	0.51	0.58	0.64						
Canton, N. Y	11			1.13														0.19			
Charles City, Iowa	7			0.92														(*)			
Charleston, S. C	11			0.51														0.40			
Charlotte, N. C	30			1.02														0.51			
Chattanooga, Tenn	15			0.89														0.29			
Cheyenne, Wyo	6–7			0.76														(*)			
Chicago, Ill	14			0.98														0.29			
Cincinnati, Ohio	15			0.57														0.29			
Cleveland, Ohio	16			0.49														0.31			
Columbia, Mo	29	3:31 p.m.	4:13 p.m.	0.65	3:42 p.m.	3:53 p.m.	0.01	0.42	0.61	0.64											
Columbia, S. C	11			0.49														0.40			
Columbus, Ohio	10			0.72														0.19			
Concord, N. H	16–17			0.94														(*)			
Concordia, Kans	28			0.43														0.35			
Corpus Christi, Tex	2			0.62														0.45			
Dallas, Tex	29			0.47														0.37			
Davenport, Iowa	23			0.78														0.53			
Dayton, Ohio	10			1.20														0.44			
Del Rio, Tex	29	3:05 p.m.	4:25 p.m.	1.03	3:14 p.m.	3:30 p.m.	T.	0.25	0.73	0.98	1.01										
Denver, Colo	27–28			1.90														(*)			
Des Moines, Iowa	21			0.73														0.37			
Detroit, Mich	9			0.55														0.37			
Devils Lake, N. Dak	22			0.66														0.16			
Dodge City, Kans	8–9			0.76														(*)			
Drexel, Nebr	21	1:07 p.m.	2:30 p.m.	1.21	1:13 p.m.	2:08 p.m.	0.01	0.14	0.62	0.75	0.80	0.87	0.90	0.90	0.91	0.92	1.03	1.19			
	22–23	10:52 p.m.	D.N.a.m.	0.96	10:52 p.m.	11:02 p.m.	0.00	0.50	0.68												
Dubuque, Iowa	7			0.63														0.56			
Duluth, Minn	9–10			0.72														(*)			
Eastport, Me	17			0.57														15			
Elkins, W. Va	23			0.49														0.41			
Ellendale, N. Dak	7–8			1.44														(*)			
El Paso, Tex	8			0.54														0.15			
Erie, Pa	7	7:24 p.m.	D.N.p.m.	0.71	7:44 p.m.	8:22 p.m.	0.03	0.10	0.28	0.31	0.35	0.41	0.50	0.56	0.63						
Escanaba, Mich	10			0.55														0.32			
Eureka, Cal	3			0.97														0.29			
Evansville, Ind	29			0.90														0.52			
Flagstaff, Ariz	27			0.13														(*)			
Fort Smith, Ark	9	4:37 a.m.	7:51 a.m.	0.89	5:24 a.m.	5:53 a.m.	0.16	0.08	0.12	0.15	0.23	0.36	0.52								
Fort Wayne, Ind	9			0.28														0.27			
Fort Worth, Tex	4			0.48														0.47			
Fresno, Cal	26			0.06														0.02			
Galveston, Tex	30	D.N.a.m.	D.N.a.m.	1.63	1:51 a.m.	2:42 a.m.	0.01	0.31	0.53	0.83	0.92	1.04	1.17	1.24	1.31	1.41	1.48	1.54			
Grand Haven, Mich	23			0.68														0.32			
Grand Junction, Colo	6			0.38														0.25			
Grand Rapids, Mich	23			0.59														0.33			
Green Bay, Wis	7			1.16														(*)			
Greenville, S. C	11			0.76														0.18			
Hannibal, Mo	22			0.70														0.62			
Harrisburg, Pa	11			0.90														0.32			
Hartford, Conn	16			1.59														0.30			
Hatteras, N. C	12			0.42														0.36			
Havre, Mont	14			0.12														0.09			
Helena, Mont	4			0.01														0.01			
Houghton, Mich	10			0.61														0.33			
Houston, Tex	29–30	D.N.p.m.	D.N.a.m.	0.70	12:04 a.m.	12:21 a.m.	0.01	0.25	0.47	0.58	0.62										
Huron, S. Dak	22			0.15														0.13			
Independence, Calif	27			0.02														0.02			
Indianapolis, Ind	30			0.75														0.44			
Iola, Kans	7			0.97														0.72			
Jacksonville, Fla	11			0.80														0.34			
Kalispell, Mont	24			0.10														0.04			
Kansas City, Mo	7			0.96														0.40			
Keokuk, Iowa	21			0.50														0.48			
Key West, Fla	27–28	D.N.p.m.	D.N.a.m.	2.09	11:30 p.m.	12:18 a.m.	0.21	0.08	0.31	0.63	0.87	1.02	1.27	1.38	1.61	1.79	1.83				
Knoxville, Tenn	29			1.12														0.52			
La Crosse, Wis	7			0.84														0.41			
Lander, Wyo	27			0.31														0.09			
Lansing, Mich	7			0.70														0.39			
Lewiston, Idaho	24			0.28														0.18			
Lexington, Ky	10			1.39														0.37			
Lincoln, Nebr	14			0.32														0.26			
Little Rock, Ark	29	9:33 a.m.	10:30 a.m.	0.57	9:49 a.m.	10:12 a.m.	0.04	0.14	0.39	0.43	0.48	0.52									
		6:57 p.m.	10:00 p.m.	1.28	7:57 p.m.	8:57 p.m.	0.22	0.12	0.26	0.34	0.44	0.47	0.56	0.63	0.67	0.72	0.78	0.93			
Los Angeles, Calif	26			0.17														0.10			
Louisville, Ky	15			0.42														0.30			
Ludington, Mich	16–17			1.09														(*)			
Lynchburg, Va	11			0.88														0.46			

* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during April, 1919, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive rate began.	5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Macon, Ga	15-16			1.08														0.48			
Madison, Wis	7			0.53														0.38			
Marquette, Mich	9-10			1.61														(*)			
Memphis, Tenn	15			1.06														0.53			
Meridian, Miss	15	11:35 a.m.	5:00 p.m.	1.89	1:32 p.m.	2:11 p.m.	0.39	0.11	0.34	0.37	0.45	0.66	0.74	1.00	1.08						
Miami, Fla	1	4:12 p.m.	4:54 p.m.	0.57	4:16 p.m.	4:33 p.m.	0.02	0.12	0.29	0.45	0.50										
Miami, Fla	17	2:19 p.m.	3:25 p.m.	1.35	2:25 p.m.	2:47 p.m.	0.01	0.31	0.60	0.87	0.99	1.03									
Milwaukee, Wis	23			0.46														0.23			
Minneapolis, Minn	7			1.72														0.36			
Mobile, Ala	10	9:10 a.m.	D. N. p.m.	2.56	9:34 a.m.	9:59 a.m.	0.02	0.19	0.46	0.80	0.92	1.05									
Mobile, Ala	15	4:55 p.m.	D. N. p.m.	2.42	5:38 p.m.	6:14 p.m.	0.16	0.20	0.62	0.89	1.14	1.23	1.32	1.37	1.40						
Modena, Utah	5			0.27														0.26			
Montgomery, Ala	15			0.92														0.69			
Moorhead, Minn	7			1.47														(*)			
Mount Tamalpais, Calif	13			0.10														0.10			
Nantucket, Mass	17			1.18														0.41			
Nashville, Tenn	10			1.25														0.39			
New Haven Conn	16			2.46														0.71			
New Orleans, La	3	2:30 p.m.	D. N. p.m.	1.77	6:12 p.m.	6:32 p.m.	0.18	0.22	0.72	0.90	1.01										
New Orleans, La	6-7	3:45 p.m.	D. N. a.m.	2.48	4:59 p.m.	5:49 p.m.	0.23	0.08	0.32	0.37	0.40	0.43	0.46	0.48	0.51	0.59	0.70				
					7:34 p.m.	8:17 p.m.	1.12	0.09	0.15	0.21	0.29	0.37	0.48	0.68	0.78	0.83					
New Orleans, La	15	3:30 p.m.	D. N. p.m.	1.53	5:38 p.m.	6:08 p.m.	0.61	0.10	0.30	0.43	0.51	0.64	0.76								
New York, N. Y	16			1.28														0.39			
Norfolk, Va	16			0.76														0.61			
Northfield, Vt	11			0.52														(*)			
North Head, Wash	19			0.70														0.28			
North Platte, Nebr	13			0.91														0.53			
Oklahoma, Okla	9	12:23 a.m.	4:15 a.m.	1.06	12:54 a.m.	1:18 a.m.	0.19	0.30	0.45	0.57	0.65	0.71									
Oklahoma, Okla	25	8:43 a.m.	2:00 p.m.	0.98	10:42 a.m.	11:08 a.m.	0.07	0.07	0.17	0.30	0.38	0.48	0.51								
Omaha, Nebr	6-7			0.63														0.50			
Oswego, N. Y	10-11			1.13														(*)			
Palestine, Tex	9			0.63														0.52			
Parkersburg, W. Va	16			0.60														0.18			
Pensacola, Fla	10	9:50 a.m.	10:45 p.m.	8.91	2:14 p.m.	3:04 p.m.	0.50	0.05	0.14	0.28	0.49	0.55	0.59	0.66	0.79	1.08	1.49				
					3:04 p.m.	3:54 p.m.		1.92	3.32	2.58	2.84	3.06	3.31	3.47	3.54	3.62	3.69				
					3:54 p.m.	4:44 p.m.		3.77	3.95	4.10	4.20	4.25	4.36	4.42	4.44	4.49	4.55				
					4:44 p.m.	5:34 p.m.		4.68	4.98	5.44	5.82	6.15	6.37	6.49	6.75	7.03	7.18				
					5:34 p.m.	5:49 p.m.		7.47	7.65	7.74											
Pensacola, Fla	15-16	5:40 p.m.	3:30 a.m.	1.75	7:13 p.m.	8:10 p.m.	0.12	0.20	0.28	0.44	0.55	0.58	0.61	0.62	0.69	0.82	1.13	1.33			
Peoria, Ill	30			0.41														0.32			
Philadelphia, Pa	16			1.59														0.36			
Phoenix, Ariz	27			0.14														0.12			
Pierre, S. Dak	6-7			1.42														0.18			
Pittsburgh, Pa	23			0.44														0.22			
Pocatello, Idaho	4			0.40														0.27			
Point Reyes Light, Calif	17			0.20														0.11			
Port Angeles, Wash	17-18			0.59														0.20			
Port Huron, Mich	10			0.54														0.23			
Portland, Me	17			0.46														0.24			
Portland, Oreg	3-4			1.24														0.27			
Providence, R. I	16			1.42														0.33			
Pueblo, Colo	23			0.82														0.27			
Raleigh, N. C	16			0.94														0.60			
Rapid City, S. Dak	13-14			0.91														(*)			
Reading, Pa	16			0.60														0.39			
Red Bluff, Calif	19			0.12														0.12			
Reno, Nev	5			0.10														(*)			
Richmond, Va	16-17	3:15 a.m.	D.N. a.m.	1.41	4:50 p.m.	5:41 p.m.	0.05	0.12	0.26	0.35	0.42	0.47	0.51	0.57	0.61	0.67	0.73	0.78			
Rochester, N. Y	8			0.43														0.22			
Roseburg, Oreg	17			0.38														0.18			
Roswell, N. Mex	25	5:17 p.m.	6:33 p.m.	1.60	5:19 p.m.	5:55 p.m.	0.02	0.15	0.49	0.67	0.93	1.08	1.38	1.53							
Sacramento, Calif	17			0.03														0.03			
Saginaw, Mich	10			0.47														0.44			
St. Joseph, Mo	9			0.88														0.32			
St. Louis, Mo	21			0.37														0.34			
St. Paul, Minn	10			0.47														0.28			
Salt Lake City, Utah	5-6			1.24														(*)			
San Antonio, Tex	29	5:15 a.m.	6:28 a.m.	1.46	5:34 a.m.	5:52 a.m.	0.01	0.36	1.04	1.36	1.40										
San Diego, Calif	26			0.29														0.10			
Sandusky, Ohio	9			0.45														0.44			
Sandy Hook, N. J	16			1.21														0.36			
San Francisco, Calif	5			0.07														0.05			
San Jose, Calif	13			0.06														0.06			
San Luis Obispo, Calif	25			0.07														0.06			
Santa Fe, N. Mex	8-9			0.62														(*)			
Sault Ste. Marie, Mich	9-10			1.37														(*)			
Savannah, Ga	4			0.30														0.17			
Scranton, Pa	15			0.42														0.32			
Seattle, Wash	13			0.27														0.16			
Sheridan, Wyo	13-14			0.28														(*)			
Shreveport, La	9	6:50 a.m.	10:50 a.m.	1.02	8:25 a.m.	8:55 a.m.	0.09	0.29	0.33	0.53	0.69	0.76	0.89								
Sioux City, Iowa	9-10			0.80														(*)			
Spokane, Wash	19			0.08														0.07			
Springfield, Ill	14			0.21														0.20			
Springfield, Mo	28			1.55														0.63			
Syracuse, N. Y	11			0.67														(*)			
Tacoma, Wash	16			0.36														0.29			
Tampa, Fla	4			0.15														0.15			
Tatoosh Island, Wash	16			0.87														0.22			
Taylor, Tex	29			0.97														0.28			
Terre Haute, Ind	15			0.66														0.41			
Thomasville, Ga	11			1.88														0.45			
Toledo, Ohio	23	12:58 p.m.	4:20 p.m.	1.16	3:17 p.m.	3:57 p.m.	0.42	0.08	0.17	0.19	0.24	0.30	0.35	0.57	0.68						
Tonopah, Nev	25			0.02														0.01			
Topeka, Kans	6-7			0.58														0.39			
Trenton, N. J	16			1.44														0.45			
Valentine, Nebr	13			0.59														0.13			
Vicksburg, Miss	9-10	7:30 p.m.	D. N. a.m.	1.74	8:09 p.m.	8:57 p.m.	0.02	0.09	0.18	0.26	0.36	0.45	0.55	0.62	0.70	0.87	0.97				
Walla Walla, Wash	4			0.63														0.19			

* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during April, 1919, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Washington, D. C.	11			1.93														0.58			
Wausau, Wis.	7			1.32														(*)			
Wichita, Kans.	28	5:25 a. m.	7:30 a. m.	0.83	6:07 a. m.	6:27 a. m.	0.03	0.23	0.49	0.56	0.70										
Williston, N. Dak.	5			0.30														0.16			
Wilmington, N. C.	16	9:44 p. m.	D. N. p. m.	1.03	10:36 p. m.	10:56 p. m.	0.45	0.09	0.27	0.41	0.50										
Winnemucca, Nev.	26			0.19														0.16			
Wytheville, Va.	30			0.96														0.36			
Yankton, S. Dak.	6			0.31														0.23			
Yellowstone Park, Wyo.	4			0.66														(*)			

* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, April, 1919.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.83	29.97	+0.08	36.5	+2.0	43.0	30.0	57	21	7.54	+3.38	7.0
Sydney, C. B. I.	48	29.95	29.99	+ .10	38.2	+3.2	45.1	31.1	58	22	5.43	+1.58	9.5
Halifax, N. S.	88	29.86	29.97	+ .01	40.4	+2.6	48.1	32.8	64	24	5.93	+1.75	5.1
Yarmouth, N. S.	65	29.89	29.96	.00	39.9	+1.0	46.4	33.5	61	26	4.45	+1.06	6.3
Charlottetown, P. E. I.	38	29.91	29.95	+ .05	37.6	+2.4	43.3	31.9	54	23	4.10	+1.45	10.0
Chatham, N. B.	28	29.95	29.98	+ .08	38.6	+3.1	46.1	31.0	63	20	3.68	+1.05	14.0
Father Point, Que.	20	29.93	29.95	+ .02	32.4	−0.8	38.5	26.4	52	14	3.56	+1.98	15.5
Quebec, Que.	296	29.64	29.97	− .02	35.3	+0.2	42.2	28.4	56	12	3.56	+1.47	13.1
Montreal, Que.	187	29.77	29.98	− .02	38.4	−1.3	45.4	31.4	66	12	3.20	+0.96	4.4
Stonecliffe, Ont.	489	29.36	29.99	− .03	30.5	−7.4	49.5	11.6	74	−12	2.61	+1.05	4.5
Ottawa, Ont.	236	29.72	29.99	− .03	39.2	−0.8	48.6	29.9	69	4	3.55	+2.05	5.5
Kingston, Ont.	285	29.68	30.00	− .02	40.3	+0.3	48.3	32.3	69	8	3.56	+1.77	0.2
Toronto, Ont.	379	29.59	30.01	− .01	42.6	+1.8	50.9	34.3	63	10	2.89	+0.52	2.6
Cochrane, Ont.	930				30.4		41.0	19.9	64	−10	1.78		1.0
White River, Ont.	1,244	28.68	30.02	− .02	32.7	−0.3	44.8	20.6	66	− 7	2.04	+0.79	2.0
Port Stanley, Ont.	592	29.36	30.02	.00	41.0	0.0	49.5	32.5	62	14	4.88	+2.41	6.5
Southampton, Ont.	656	29.27			40.8	+2.1	48.6	33.0	66	12	2.59	+0.79	1.5
Parry Sound, Ont.	688	29.30	30.00	− .02	40.0	+2.4	50.8	29.2	68	1	2.78	+0.87	0.5
Port Arthur, Ont.	644	29.32	30.03	.00	36.6	+3.1	45.9	27.3	68	5	0.72	−1.00	T.
Winnipeg, Man.	760	29.18	30.03	+ .01	41.7	+5.8	52.3	31.2	70	13	1.11	+0.06	4.0
Minnedosa, Man.	1,690	28.17	30.02	+ .01	39.9	+3.9	50.7	29.3	69	12	2.38	+1.32	0.5
Le Pas, Man.	860				37.9		49.1	26.7	64	10	0.30		0.5
Qu'Appelle, Sask.	2,115	27.68	29.95	− .04	41.6	+4.2	53.0	30.3	73	16	1.66	+0.61	2.0
Medicine Hat, Alb.	2,144	27.59	29.86	− .06	49.0	+4.5	62.2	35.8	80	25	1.07	+0.33	2.4
Moose Jaw, Sask.	1,759												
Swift Current, Sask.	2,392	27.33	29.96	.00	44.9	+3.6	56.2	33.6	74	21	2.10	+1.17	11.8
Calgary, Alb.	3,428	26.37	29.95	+ .05	45.0	+5.4	59.3	30.8	79	21	0.50	−0.14	
Banff, Alb.	4,521	25.33	29.93	+ .03	38.7	+3.4	50.1	27.3	68	17	0.76	−0.32	3.9
Edmonton, Alb.	2,150	27.58	29.87	− .02	45.1	+5.2	58.5	31.7	72	22	0.75	−0.13	T.
Prince Albert, Sask.	1,450	28.40	29.99	+ .01	43.5	+7.4	56.2	30.9	74	12	0.16	−0.67	
Battleford, Sask.	1,592	28.18	29.93	− .04	45.5	+8.3	57.9	33.1	77	17	0.24	−0.23	
Kamloops, B. C.	1,262	28.73	30.03	+ .10	51.2	+2.3	64.4	37.9	78	24	0.46	+0.07	
Victoria, B. C.	230	29.80	30.06	+ .05	48.9	+2.1	55.5	42.4	67	37	2.90	+0.53	
Barkerville, B. C.	4,180	25.64	29.98	+ .12	35.2	+2.1	44.6	25.9	59	15	2.81	+0.99	15.4
Triangle Island, B. C.	680												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151	29.93	30.10	+ .05	63.9	0.0	69.4	58.5	73	53	4.64	+0.46	

SEISMOLOGY.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D C., June 3, 1919.]

TABLE 1.—*Noninstrumental earthquake reports, April, 1919.*

Day.	Approximate time, Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		ARKANSAS.								
	H. m.		° ′	° ′			Sec.			
Apr. 8	8 40	Ravenden	36 30	91 11	3-4				May not be a quake	L. H. Walker.
		CALIFORNIA.								
1	5 46	Calexico	32 41	115 30	3	1		Rumbling		H. M. Rouse.
13	14 18	Stanford University	37 26	122 12	2	1	2	None		Dr. S. D. Townley.
19	9 24	Calexico	32 41	115 30	3	1	3	Rumbling	Preceded by a jar	H. M. Rouse.

NOTE.

The following note by D. L. Hazard, Chief of Division of Terrestrial Magnetism, U. S. Coast and Geodetic Survey, gives some records of the sea waves produced by the earthquake of April 30, 1919:

"The tide gages of the United States Coast and Geodetic Survey at San Diego, and San Francisco, Calif., and Honolulu, Hawaii, recorded a marked tidal disturbance on April 30, 1919.

"At San Francisco, the first effect is shown on the tidal record at $18^h 40^m$ Greenwich mean time, at San Diego at $18^h 45^m$, and at Honolulu at $13^h 45^m$. The principal effect lasted from 12 to 20 hours and there are indications of a disturbance some hours later, although it can not be determined whether the effect was produced by wind or by the earthquake.

"The records of this earthquake from the seismographs at the magnetic observatories of this bureau are somewhat confused, and suggest the possibility that there may have been two earthquakes at nearly the same time, but the indications are that the principal earthquake occurred at about $7^h 16^m$ Greenwich mean time, the origin being somewhere in the southern Pacific."

TABLE 2.—*Instrumental seismological reports, April, 1919.*

(Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.)

[For significance of symbols see REVIEW for January, 1919, p. 59.]

Alabama. *Mobile. Spring Hill College.* Earthquake Station. Cyril Ruhlmann, S. J.

Lat., 30° 41′ 44″ N.; long., 88° 08′ 46″ W. Elevation, 60 meters.

Instrument: Wiechert 80 kg.; astatic, horizontal pendulum.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			H. m. s.	Sec.	μ	μ	km.	
Apr. 17		eP	20 57 10					E-W component undamped.
		iS_E	21 00 10					
		iS_N	21 00 25					
		L	21 00 45	5				
		M_E	21 00 50	5	*11,000			
		M_N	21 05 40	5		*5,000		
		F	21 17 ..					
30		e_E	7 35 50					Poor record.
		i	7 41 55					
		e_N	7 43 42					
		i	8 10 00					
		F	8 42 ..					

*Trace amplitude.

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 57° 03′ 00″ N.; long., 135° 30′ 00″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants. .{E: V 10, T_0 17.7; N: V 10, T_0 16.6}

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			H. m. s.	Sec.	μ	μ	km.	
Apr. 17		eP_E	21 10 06					
		eP_N	21 10 12					
		eL_E	21 21 30					
		eL_N	21 26 15					
		M_E	21 27 20	16	20			
		M_N	21 30 30	15		10		
		F_N	21 31 ..					
		F_E	21 36 ..					
18		eL_E	21 26 00					Nothing on N-S.
		M_E	21 28 ..	10	10			
		F	21 36 ..					
30		P_N	7 29 37	4				
		eP_E	7 29 40					
		eS_N	7 40 49	9				
		eS_E	7 41 11	11				
		eL_E	8 04 14	18				
		eL_N	8 04 42					
		M_E	8 19 41	17	40			
		M_N	8 19 48	16		60		
		C_N	8 20 ..	16				
		C_E	8 31 ..	16				
		F_N	9 03 ..					
		F_E	9 57 ..					

TABLE 2.—*Instrumental seismological reports, April, 1919*—Continued.

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Wm. H. Cullum.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments; Two Bosch-Omori, 10 and 12 kg.

Instrumental constants		V	T_0
	E	10	15
	N	10	18

Date.	Character.	Phase.	Time.	Period T.	Amplitude.		Distance.	Remarks.
					A_E	A_N		
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Apr. 17		P_N	20 58 29	4				
		P_E	20 58 48	2				
		iS_N	21 03 06					
		iS_E	21 03 11					
		L_N	21 06 35	20				
		L_E	21 06 40					
		M_E	21 09 50		*130			
		M_N	21	18		*6,650		Amplitude greater than given. Stylus off from 21h 10m to 21h 13m.
		C	21 14 ..	16				
		F	21 26 ..					
18		P_N	21 04 37	3				
		eS_E	21 07 23					
		L_E	21 08 30					
		L_N	21 09 00	19				
		M_E	21 10 23	9	*320			
		C_E	21 11 ..	7				
		M_N	21 11 20	9		*300		
		Cn	21 14 ..					
		Fe	21 15 ..					
		Fn	21 31 ..					
19		e_N	3 08 23			*50		No definite phases.
		e_E	3 08 37		*30			
		F	3 14 ..					
30		P_N	7 29 22	4				
		eL_N	7 54 15					
		M_N	8 13 44	16		*440		
		C_N	8 19 ..					
		F_N	10 22 ..					

* Trace amplitude.

California. *Berkeley. University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(*See* Bulletin of the Seismographic Stations, University of California.)

California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters.

(*See* Bulletin of the Seismographic Stations, University of California.)

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Apr. 5			.. .. ..		*100	*100		Tremors during the 24 hours preceding 15h on dates given.
6			.. .. ..		*150	*200		
7			.. .. ..		*100	*200		
8			.. .. ..		*50	*50		
11			.. .. ..		*300	*300		
14			.. .. ..		*200	*200		
15			.. .. ..		*100	*100		
18			.. .. ..		*200	*200		
20			.. .. ..		*50	*50		
21			.. .. ..		*50	*50		
25			.. .. ..		*250	*300		
26			.. .. ..		*50	*100		
30			.. .. ..		*50	*50		

* Trace amplitude.

California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J.

Lat., 37° 26′ 36″ N.; long., 121° 57′ 03″ W. Elevation, 27.43 meters.

(*See* Record of the Seismographic Station. University of Santa Clara.)

Colorado. *Denver. Sacred Heart College.* Earthquake Station. A. W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters.

Instrument: Wiechert 80 kg., astatic, horizontal pendulum.

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Apr. 3		L_N	1 03 ..					Sinusoidal waves of small amplitude. Large period.
		M_N	1 07 ..					
		F_N	1 12 ..					
5		L_N	1 08 ..					Irregular sinusoidal.
		F_N	1 15 ..					
17		L	21 03 ..					Very distinct. P not discernible.
		M_N	21 04 ..					
		M_E	21 11 ..					
		F_E	21 22 ..					
		F_N	21 24 ..					
18		P_E	22 08 ..					P not discernible on N-S.
		L	22 11 ..	9-10	*500	*5,500		
		M_E	22 13 ..		*5,500			
		M_N	22 14 ..			*5,500		
		F	22 22 ..					
30		P	7 39 ..					
		S_N	7 45 30					S_E obscured by time marks.
		L_E	7 57 ..	15	*3,000			
		L_N	7 59 ..	15		*2,100		
		M	8 08 ..	20-21	*3,000	*2,100		
		F_E	9 11 ..					
		F_N	9 12 ..					

*Trace amplitude.

District of Columbia. *Washington. U. S. Weather Bureau.*

Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.

Instrument: Marvin (vertical pendulum), undamped. Mechanical registration.

Instrumental constants.. V 110 T_0 6.4

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Apr. 2		iP	0 54 38				8,950	P very sharply defined on N-S. Other phases not discernible.
		S_E	1 04 46					
		F	1 30 ..					
17		P_E	11 42 10				3,810	
		S_N?	11 47 46					
		L	11 51 40					
		F	13 55 ..					
17		P	20 58 51				2,050	
		S	21 02 19					
		L	21 03 40	24				
		M	21 08 45		*7,500	*7,500		Movement dies out on E-W much sooner than on N-S.
		L	21 16 00	16				
		F	22 30 ..					
18		P	21 07 34				3,600	
		S	21 12 58					
		L?	21 16 28					
		M_N	21 50 00			*6,000		
		F	22 20 00					
19		P?	3 02 42					No L waves visible
		S?	3 08 10					
		F	3 35 ..					
21		P	11 34 38				4,890	
		S	11 41 14					
		L	11 47 50	20				
		F	12 30 ..					
21		eL_N	15 54 50	18				
		F	16 02 00					
27		P?	0 42 53					Record indistinct.
		eL	1 35 00					
		L	1 41 00	16				
		F	1 55 00					
28		P	6 51 52				2,930	Salvador.
		S	6 56 30					
		L?	6 58 45					
		L	7 03 30	12				
		F	7 35 00					
30		P	7 31 29				9,850	Large record, but difficult of interpretation.
		S?	7 42 20					
		L	8 01 25	60				
		L	8 10 ..	20				
		L	8 27 ..	16				
		F	11 40 ..					

*Trace amplitude.

TABLE 2.—*Instrumental seismological reports, April, 1919*—Continued.

District of Columbia. *Washington. Georgetown University.* F. A. Tondorf, S. J.

Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite.

Instruments: Wiechert 200 kg. astatic horizontal pendulums, 80 kg. vertical.

Instrumental constants	V	T_0	ε
E	165	5.4	0
N	143	5.2	0
Z	*80*	*3.0*	*0*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ.*	*μ.*	*km.*	
Apr. 17	....	eP_E	11 41 24	......	......	......	......	Not shown on N-S. Sheets changed at 13h 09m, quake still going on.
		S_E?	11 52 08	......	......	......	......	
		L_E	12 03 27	22	......	......	......	
		L_E	12 18 ..	22	......	......	......	
17	....	eP_E	20 58 52	......	......	......	......	
		eP_N	20 58 53	......	......	......	......	
		S	21 03 38	......	......	......	......	
		eL_E?	21 05 30	......	......	......	......	....
		M_E	21 08 38	6	*1,900	......	......	
		M_E	21 09 21	6	*1,500	......	......	
		M_E	21 10 00	6	*1,700	......	......	
		M_N	21 12 02	14	......	*1,600	......	
		F	22 15 ..	......	......	......	......	
18	....	eP_E	21 07 30	......	......	......	......	P_N hardly shows. Microseisms present.
		S	21 13 00	......	......	......	......	
		eL	21 16 00	6	......	......	......	
		L_N	21 18 57	19	......	......	......	
		L_E	21 19 10	16	......	......	......	
		M_N	21 20 03	11	......	*800	......	
		M_E	21 20 31	......	*900	......	......	
		F	22 20 ..	......	......	......	......	F difficult.
19	....	L_E	{ 3 21 13 3 25 ..	......	......	......	......	No other phases discernible. Mi croseisms present.
21	....	P_E	11 34 34	......	......	......	......	N-S poorly defined.
		S	11 41 12	......	......	......	......	
		eL_E	11 47 ..	38	......	......	......	F lost in changing sheets.
28	....	eP	6 51 45	......	......	......	......	eP poorly defined on N-S.
		S_E?	6 56 25	......	......	......	......	
		eL_E	7 01 12	16	......	......	......	
		F	7 30 ..	......	......	......	......	
30	....	eP	7 31 20	......	......	......	......	eP and other phases poorly defined on N-S.
		PR1	7 35 53	......	......	......	......	
		S_E	7 42 20	......	......	......	......	
		S_N?	7 42 23	......	......	......	......	Vertical component poorly defined.
		eL_E	8 01 06	22	......	......	......	
		M_E	8 17 53	19	*5,200	......	......	
		M_N	8 20 18	16	......	*1,800	......	
		M_E	8 20 20	19	*4,400	......	......	
		M_E	8 24 20	16	*3,800	......	......	
		F	13 23 ..	......	......	......	......	

* Trace amplitude.

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee f the British Association.

Instrumental constant..T_0 18.1. Sensitiveness 0.40″ arc tilt=1 mm.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
Apr. 17	....	P	11 31 48	......	......	......	......	
		S	11 38 24	18	......	......	......	
		L	11 49 00	22	......	......	......	
		M	11 54 54	19	*2,000	......	......	
		C	12 03 ..	17	......	......	......	
		F	14 45 ..	......	......	......	......	
17	....	P	21 03 54	19	......	......	......	
		S	21 12 30	18	......	......	......	
		L	21 23 30	18	......	......	......	
		M	21 26 06	20	*4,000	......	......	
		C	21 43 ..	18	......	......	......	
		F	23 03 ..	......	......	......	......	
18	....	P	21 21 48	......	......	......	......	Probably local.
		M	21 27 06	15	*900	......	......	
		F	22 45 ..	......	......	......	......	
21	....	L	13 40 48	19	......	......	......	
		M	13 45 00	......	*100	......	......	
		F	14 06 ..	......	......	......	......	
22	....	P	3 01 30	18	......	......	......	
		L	3 10 06	21	......	......	......	
		M	3 16 30	22	*300	......	......	
		C	3 21 ..	20	......	......	......	
		F	4 12 ..	......	......	......	......	
23	....	P	7 21 12	19	......	......	......	
		S or L.	7 24 06	......	......	......	......	
		M	7 24 48	......	*500	......	......	
		M	7 47 ..	......	*500	......	......	
		F	8 00 ..	......	......	......	......	
27	....	L	0 46 ..	19	......	......	......	
		M	1 16 30	17	*700	......	......	
		C	1 20 30	......	......	......	......	
		F	1 35 ..	......	......	......	......	
28	....	L	7 17 ..	21	......	......	......	
		M	7 22 30	......	*300	......	......	
		F	7 38 ..	......	......	......	......	
30	....	P	7 26 00	......	......	......	......	The times given for S and L refer to points of marked increase of amplitude.
		S	7 32 24	......	......	......	......	
		L	7 35 42	19	......	......	......	
		M	7 41 30	......	*35,000	......	......	
		F	13 02 ..	......	......	......	......	

* Trace amplitude.

TABLE 2.—*Instrumental seismological reports, April, 1919*—Continued.

Illinois. *Chicago.* University of Chicago. U. S. Weather Bureau.

Lat., 41° 47′ N.; long., 87° 37′ W. Elevation, 180.1 meters.

Instruments: Two Milne-Shaw horizontal pendulums, 0.45 kg.

Instrumental constants	V	T_0	ε	Sensitivity.
E	150	12	20:1	1″ arc tilt=26.6 mm.
N	150	8	20:1	1″ arc tilt=13.2 mm.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			H. m. s.	Sec.	μ	μ	km.	
Apr. 2		P	0 54 35					S? T_0 of N-S 12s and sensitivity 26.6 until Apr. 21.
		L	1 31 00					
		L	1 40 30	24				
		L	2 22 00	16				
		F	3 00 00					
16		L_E	4 04 50	24				Record confused in tangled lines on N-S.
		L_E	4 13 30	20				
		F	4 40 00					
17		P	11 41 14				4,175	E-W trace wandered off sheet at 12h 36m, record lost for 1 hour. L continues on N-S with about same amplitude for 1½ hours or more.
		S	11 47 11					
		L	11 50 45					
		L	12 12 40	38				
		F	14 30 00					
17		P	20 58 50				1,970	L waves irregular and continue with uniform period for over 2 hours on both components, though not as large on E-W as on N-S.
		S	21 02 10					
		L	21 04 30					
		M_N	21 05 13	20		120		
		M_N	21 13 35	20		100		
18		F	0 24 30					
18		P	21 07 00				2,960	
		S	21 11 40					
		L	21 14 43					
		M	21 16 00		67	67		
		M_N	21 18 00			67		
		F	23 20 ..					
19		P	3 02 51				3,000	
		S	3 07 34					
		L	3 13 29	8				
		F	4 10 00					
21		P	11 35 36				5,925	Record lost after 12h 45m, when trace wandered off sheet.
		S	11 43 08					
		L	11 51 31	26				
21		P	15 55 50	15				
		F	16 20 ..					
22		P	3 03 27				8,430	
		S	3 13 09					
		L?	3 26 00					
		L	3 31 00	18				
		L	3 44 ..	18				
		F	5 10 ..					
23		e?	7 23 00					
		L	7 53 00					
		L	8 02 00	16				
		L	9 24 ..	24				Possibly Lrepl.
		L	9 33 ..	18				
		F	9 50 ..					
27		P?	0 42 07					P and S doubtful. Instrument adjusted during beginning of quake.
		S	0 58 30					
		L	1 18 10					
		L	1 26 00	28				
		L	1 38 ..	17				
		F	2 40 ..					
28		P	6 51 55				2,940	L waves irregular both as to period and amplitude.
		S	6 56 34					
		L	6 59 24					
		F	8 40 ..					
30		P	7 30 52				9,510	
		S	7 41 28					
		L	7 59 00	50				
		M_E	8 09 ..		147			Amplitudes largest on E-W.
		M_E	8 13 ..		266			L waves with amplitudes of 67 μ or more continue for nearly 2 hours. F in microseisms sometime after 13h.
		M_E	8 21 ..		420			
30		P?	7 34 48					All phases confused with preceding quake.
		S?	7 45 18					

Kansas. *Lawrence. University of Kansas.* Department of Physics and Astronomy. F. E. Kester.

Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.

Instrument: Wiechert.

Instrumental constants	V	T_0	ε
E	177	3.4	4:1
N	205	3.4	4:1

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			H. m. s.	Sec.	μ	μ	km.	
Apr. 17		iP_N	20 58 23					
		eP_E	20 58 28					S uncertain.
		iL_E	21 02 55					
		iL_N	21 02 56					
		M_N	21 03 23			*3,750		
		M_E	21 03 25		*3,200			
		F	21 58 ..					
18		eP	21 06 04					
		S	21 10 14					
		L_E	21 13 13					
		L_N	21 13 14					
		M_N	21 15 15			*4,700		
		M_E	21 15 17		*6,250			
		F	21 58 ..					
30		P_E	7 30 17					
		P_N	7 30 19					
		S_E?	7 34 16?					Corresponding S_N not found. Possibly S_E?. Possibly S_N?.
		L_E?	7 41 09					
		L_N?	7 42 02					
		L?	8 00 09					
		M_N	8 02 25			*1,800		
		M_E	8 15 49		*5,000			
		F	9 45 ..					

* Trace amplitude.

Maryland. *Cheltenham. Magnetic Ogservatory.* U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants	V	T_0
E	10	15
N	10	15

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919			H. m. s.	Sec.	μ	μ	km.	
Apr. 17		P_N	20 58 55	3				
		iP_E	20 58 58	4				
		iS_N	21 03 44	14				
		S_E	21 03 48	6				
		L_E	21 09 19	16				
		L_N	21 09 42	17				
		M_E	21 12 21	12	*440			
		M_N	21 12 27	15		*1,800		
		C	21 16 ..	14				
		F_E	21 32 ..	14				
		F_N	22 12 ..	13				
18		eP_E	21 08 39					
		eP_N	21 08 54					
		S_N	21 13 13	8				
		L_N	21 19 17					L not well marked on E-W.
		L_E	21 20 20					
		M	21 20 31	13	*20	*570		
		F_E	21 33 ..					
		F_N	22 07 ..					
28		eP_N	6 51 54					
		eP_E	6 51 59					
		L_N	7 00 59					
		M_N	7 03 44			*30		
		F_E	7 07 ..					
		C_N	7 13 ..					
		F_N	7 27 ..					
30		e_E	7 34 33					Early phases not well defined. iP_E may be PR.
		iP_E	7 35 51	4				
		eP_N	7 35 54	4				
		eS_N	7 44 00	10				Possibly SR_N. at 7h 51m, 26s.
		L_E	8 11 47	19				
		eL_N	8 17 ..					
		M_N	8 22 31	14		*1,580		
		M_E	8 24 41	15	*1,700			
		C	8 56 ..	15				
		F_E	10 13 ..	16				
		F_N	10 58 16					

*Trace amplitude.

TABLE 2.—*Instrumental seismological reports, April, 1919*—Continued.

Massachusetts. *Cambridge. Harvard University Seismographic Station*, J. B. Woodworth.

Lat., 42° 22′ 36″.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration).

Instrumental constants	V	T_0	ϵ
E	80	23	0
N	50	25	4:1

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919			H. m. s.	Sec.	μ	μ	km.	
Apr. 2		e	1 52 29	8				Cf. Ottawa, eL 1^h 46^m.
		L_N	1 55 30	20				Slight record on N-S.
		F	2 04 02					
15		M_N?	{17 36 34 17 38 00	28 24				Possibly not seismic; among irregular waves running from 13^h 57^m to 21^h 30^m.
16		L_N	3 59 52	20				Cf. Ottawa eL 4^h.
		L	4 12 40	18				
		L	4 19 36	16				
		F?	4 20 50					
17		*O*?	*11 28* ..				7,850*	Distance may be as much 8.050 km. Minute ticks failed during registration of P. Changed E-W record before 11^h 55^m.
		P_N?	11 49 19					
		S_N?	11 58 41					
		S_E	11 59 46					
		eL_N	12 12 42	64				
		L_E	12 20 41	32				
		L	12 27 43	22.5				Not Lrep.
		M_E	12 27 53	20				
		F	12 53 ..					
17		*O*	*20 58 18*				3,350	E-W gives distance 3,450 km.
		iP_N	20 59 42	4				
		iP_E	20 59 43	4				
		S_N	21 04 49					
		S_E	21 04 57	12				
		i_N	21 09 53					Large waves like L.
		L	21 10 29	26				
		M_N	21 12 31					
		M_E	21 13 24	17	*29,000			
		M_N	21 14 25					
		M_E	21 15 26	17	*63,000			
		M_N	{22 23 45 22 35 50}					A lenticular group of waves. E-W styles off drum from 22^h 15^m 42^s to 22^h 16^m 48^s. Automatic gong rang during occurrence of M.
		F	23 34 ..					
18		*O*	*21 01 00*				4,120	Cf. Ottawa, *O* 21^h 01^m 02^s.
		P_E	21 08 27	3				
		i_N	21 09 53	6				
		i_E	21 09 55	6				
		S_N	21 14 21	12				
		S_E	21 14 28	11				
		L_N	21 20 04	21				
		L_N	21 21 33	24				
		L_E	21 22 48	16				
		M_E	21 23 10	12	*6,000			Damped 1.5:1.
		M_E	21 24 47	11	*4,000			
		F	22 45 ..					
19		*O*	*3 05 50*				3,100	P masked by microseism of 4 sec. period. N-S masked throughout.
		S_E	3 16 59	6				
		eL_E	3 19 46	20				
		e_N	3 20 00	6.5				
		L_E	3 21 53	20				
		L_E	3 22 42	15-18				
		L_N	3 23 38	10				
		F_E	3 40 ..					
21		*O*	*11 26 17*				4,700	42° 18′ of arc.
		P_N	11 34 25					
		P_E	11 34 26					
		i_E	11 35 22	6				
		S_N	11 40 51	6				
		S_E	11 40 54	10				

Massachusetts. *Cambridge. Harvard University Seismographic Station*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919			H. m. s.	Sec.	μ	μ	km.	
Apr. 21		eL_N?	11 45 11	24				
		eL_E?	11 45 26	15				Followed by waves of 20 sec. period. F merges into local disturbances peculiar to morning hours.
		F	12 22 ..					
		e_N?	15 51 04	13				Cf. Ottawa, eL 15^h 35^m.
		e_E	15 58 36	7				
		L_N	{15 59 44 16 01 04}	15		*500		
		F_E	16 14 37					
27		*O*?	*0 55 45*				7,480	Distance probably greater than given.
		S_N?	1 15 33	6				
		S_E?	1 15 47	6				
		e_E	1 21 58	9				
		e_E	1 23 31					
		L_E	1 28 38	24				Amplitude slight.
		L_N	1 30 34	24				
		L_N	1 34 19	20				
		F_E	1 47 30					
28		*O*?	*6 44 22*				4,420?	P in microseisms.
		e_E	6 57 24					
		eP_N?	6 57 55	3.5				
		i_N	6 58 15	4				
		S_N?	6 58 21	6				
		i_N	6 59 16					Pendulum shifted north.
		eL_E	7 03 44	18				
		eL_N	7 03 59	16				
		L_N	7 06 11	22				
		L_N	7 06 33	15				
		F	7 49 40					
28		L_N	{11 32 00 11 34 06}	20				Amidst irregular waves of long periods; less distinct on E-W.
30		*O*	7 *18 10*				10,390	93.°5 of arc. Cf. La Paz, *07h 18m 20s*; distance, 9,550 km. Harvard and La Paz give intersection in longitude 158.5°.
		eP_E	7 31 31	4				
		P_N	7 32 20	4				
		#P_NR_1	7 36 18	3				
		#P_ER_1	7 36 29	3.5				
		P_ER_2	7 37 18	7				
		P_NR_2	7 37 45	6.5				
		S_N	7 42 50					
		S_E	7 42 56					
		#i_N	7 44 14	19				
		#i_E	7 46 05	18				
		S_ER_1	7 47 00					E-W damped 1.5:1 by magnet.
		S_NR_1	7 48 00	16				
		#SP-P_N	7 52 10	47				Looks like eL of a superposed second quake. i_N 7^h 44^m 14^s looks like iS of a second quake. Times marked # fit into a supposed quake, distance 6,370 km. *O* *7 26 26* iP_N 7 36 18 S_N 7 44 19 eL_N 7 52 10 M 8 00 ..
		S_NR_2	7 53 00					
		i_E	7 59 30					
		#i_N	8 00 00					
		eL_N	8 02 42	49				
		L_N	8 05 10	53.5				
		L_E	8 05 13	20				
		M_N	8 17 23	18		*61,500		
		M_E	8 18 45	15	*60,000			
		M_E	8 20 30					
		M_E	8 21 00					
		M_N	8 21 36					N-S stylus left drum and no further record on N-S. These maxima with a period of about 15 sec. and average trace amplitude of *60,000 μ continue until 8^h 47^m. The damping is too slight.
		M_E	8 22 00					
		M_E	8 24 00					
		C_E	9 19 ..					
		L_{rep1}	9 37 00					
		M	9 38 ..					
		M	9 39 ..					
		L_{rep2}	11 10 ..					
		L_{rep3}	12 32 ..					F may be leter, record changed.
		F	12 37 ..					

*Trace amplitude.

TABLE 2.—*Instrumental seismological reports, April, 1919*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 1 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instrument: Wiechert 80 kg. astatic, horizontal pendulum.

Instrumental constants.. V 80, T_0 7, ϵ 5:1

(Report for April, 1919, not received.)

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration).

Instrumental constants..	V	T_0	ϵ
E	13	22	4:1
N	14	25	4:1

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1919.			H. m. s.	Sec.	μ	μ	km.	
Apr. 17		e_E	11 47 18	4				
		e_E	11 51 21	4				
		e_N	11 51 25	4				
		S_E	11 57 54	20				
		S_N	11 58 18	18				
		L_N	12 12 20	45				
		L_E	12 15 20	30				
		L	13 24 ..					
		F_E	14 06 ..					
17		P_N	20 59 01	5				
		S_E	21 04 19	9				
		M_N	21 12 45	17		*3,800		
		F_E	22 22 ..					
18		eP_E	21 08 46	7				
		eP_N	21 08 53	5				
		eS_N	21 13 21	8				
		e_N	21 16 18	7				
		L_N	21 19 48	15				
		F_E	22 12 ..					
21		P_E	11 34 31	4				
		P_N	11 34 33	4				
		e	11 37 35	5				
		S_E?	11 41 21	12				
		S_N?	11 41 23	5				
		L_N	11 47 19	12				
		L_E	11 47 21	9				
		F	12 20 ..					
28		e_E	6 57 55	5				
		e_N	6 58 53	6				
		L_E	7 01 56	15				
		L_N	7 02 36	12				
		F_E	7 33 ..					
30		eP_E	7 31 24	5				
		PR_1	7 35 19	5				
		S_E	7 42 21	9				
		S_N	7 43 16	8				
		L_N	8 01 16	60				
		M_E	8 24 56	16	*5,700			
		F_E	12 08 ..					

* Trace amplitude.

New York. *New York. Fordham University.* D. H. Sullivan, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert, 80 kg.

Instrumental constants..	V	T_0	ϵ
E	72	5.0	0
N	72	5.0	0

(Report for April, 1919, not received.)

Panama Canal Zone. *Balboa Heights.* Governor, Panama Canal.

Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori, 100 kg.

Instrumental constants.. V 35, T_e 20

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1919.			H. m. s.	Sec.	μ	μ	km.	
Apr. 17		P_E	20 56 11				1,130	
		P_N	20 56 12					
		S_N	20 58 34					
		S_E	20 58 51					
		L_N	20 59 26					
		L_E	20 59 55					
		M_E	21 01 20		*900			
		M_N	21 01 38			*1,800		
		F	21 28 00					
28		P_E	6 48 22					San Salvador.
		P_N	6 48 27					
		S_N	6 49 53					
		L_N	6 51 09					
		M_N	6 53 37			*500		
		F	7 15 00					
30		P_N	7 30 40				10,400	
		P_E	7 30 45					
		S_E	7 41 49					
		S_N	7 42 00					
		L_N	7 57 00					
		L_E	8 02 20					
		M_E	8 18 00		*2,000			
		M_N	8 18 30			*2,000		
		F_E	10 03 00					
		F_N	10 15 00					

* Trace amplitude.

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. W. M. Hill.

Lat., 18° 09′ N.; long., 65° 27′ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants..	V	T_0
E	10	18
N	10	20

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1919.			H. m. s.	Sec.	μ	μ	km.	
Apr. 17		eP_E	20 58 44	7				
		eP_N	20 59 17	7				
		iS_E	21 03 44	19				
		eS_N	21 04 26					
		L_N	21 06 15	24				
		L_E	21 06 42	19				
		M_N	21 06 45	30		100		
		M_E	21 12 44	14	160			
		C_N	21 17 ..	14				
		C_E	21 19 ..	14				
		F_N	21 29 ..					
		F_E	21 44 ..					
21		eP_E	11 31 35	9				
		eP_N	11 31 43					
		eS_E	11 35 30	10				
		eS_N	11 36 12					
		eL_E	11 37 35					
		M_E	11 42 40	8	10			
		M_N	11 43 25	7				
		F_E	11 59 ..					
		F_N	12 01 ..					
28		eP_E	6 55 32					
		eL_E	6 58 53					
		M_E	7 01 48	11	10			
		F_E	7 11 ..					
30		eP_N	7 35 31	7				This may be PR.
		eP_E	7 36 31	8				
		S_E	7 46 13					
		S_ER	7 52 28					
		S_NR	7 52 45					
		eL_N	8 03 ..	38				
		L_E	8 12 27	22				
		L_N	8 14 50					
		M_N	8 16 25	18		120		
		M_E	8 31 17	17	180			
		F_N	9 55 ..					
		F_E	10 29 ..					

TABLE 2.—*Instrumental seismological reports, April, 1919*—Continued.

Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.

Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.

Instruments: Two Bosch-Omori, mechanical registration.

Instrumental constants.. E: V 10, T_0 15; N: V 10, T_0 16

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			H. m. s.	Sec.	μ	μ	km.	
Apr. 17		e	20 58 58					
		S?	21 01 24					
		L	21 05 00	20				
		L	21 11 36	20				
		M_N	21 16 00	16		*10,000		
		F	22 10 00					
18		e	21 14 25					
		L	21 54 00	14				
		F	22 00 ..					
21								Trace on N-S about 11h 45m but no time marks.
28		eL_E	7 00 00					Does not show on N-S.
		L_E	7 04 00	12				
		F	7 20 ..					
30		e	7 35 53					All phases indistinct.
		L	8 12 00	24				L continues more or less irregular for over ½ hour, largest on E-W.
		L	8 17 00	18				
		F	11 00 ..					

* Trace amplitude.

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80 kg. vertical seismograph.

Instrumental constants.. V 120, T_0 26

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			H. m. s.	Sec.	μ	μ	km.	
Apr. 2		e?	0 57 22					e, irregular, may be local.
		eL	{1 46 .. 2 05 ..}	26				eL are regular sinusoidal waves of small amplitude.
16		eL	{4 00 .. 4 20 ..}	15				Very small amplitude. Barely discernible.
17		*O*	*11 28 35*				9,760	
		P?	11 41 25					
		S_E?	11 52 12					
		L	12 11 54	48				
		L	12 20 ..	36				
		L	12 35 ..	16				
		L	13 05 ..	16				
		L	13 30 ..	22				F 14h.
17		*O*	*20 53 02*				3,590	
		iP	20 59 49					
		eS	21 05 12					
		eL?	21 08 30					
		M	21 15 ..	17				
		L	21 36 ..	15				
		L	21 55 ..	14				
		F	22 30 ..					

Canada. *Ottawa. Dominion Astronomical Observatory*—Con.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			H. m. s.	Sec.	μ	μ	km.	
Apr. 18		*O*	*21 01 02*				3,940	
		P	21 08 16					
		PR	21 09 30					
		S	21 14 00					
		eL	21 20 18					
		L	21 22 ..	8				
		L	21 35 ..	8				
		L	21 43 ..	8				
		L	22 06 ..	8				
		F	22 30 ..					
19		iS	3 09 38					P lost in microseisms.
		L	{3 19 30 3 33 ..}	8				eL?.
		F	3 50 ..					
21		eL	{15 55 .. 16 10 ..}	17				
22		eL	{3 11 .. 3 25 ..}	13				F merges into next quake.
22		eL	{3 38 .. 4 05 ..}	18				e in preceding quake.
		F	4 30 ..					Amplitudes very small.
23		e	7 35 ..					
		e	7 44 ..	8				
		eL_N	7 53 ..	36				
		L	8 02 ..	?				
		L	8 19 ..	?				
		L_E	8 26 ..	16				
		L_E	8 32 ..	14				
		F	8 45 ..					Record complete up to Apr. 23; next report will be issued about July 1.

Canada. *Toronto. Dominion Meteorological Service.*

Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North; in the meridian.

Instrumental constant.. T_0 18. Pillar deviation, 1 mm. swing of boom=0.45″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			H. m. s.	Sec.	μ	μ	km.	
Apr. 15		L	23 41 36					Doubtful as to being seismic.
		M	23 43 30		*200			
16		F	0 02 36					
16		e	4 03 12					
		L	4 09 48		*100			
		F	4 34 12					
17		P	11 40 42?				10,600	Possibly Japan.
		iS	11 52 06					
		i	12 03 24					
		e	12 06 18					
		eL	12 30 18					
		M	12 32 12		*100			
		eL	13 11 12					F merges into next quake.
17		eL	13 36 54					Possibly same origin as preceding. P and S lost in previous quake.
		eL	13 42 24					
		M	13 43 30		*800			
		iL	13 53 36					
		F	14 27 48					

TABLE 2.—*Instrumental seismological reports, April, 1919*—Continued.

Date.	Char-acter.	Phase.	Time.	Period T.	Amplitude.		Dis-tance.	Remarks.
					A_E	A_N		
Canada. *Toronto. Dominion Meteorological Service*—Continued.								
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Apr. 17		P	21 00 00				3,810	P not well defined S of large amplitude.
		iS	21 05 36					
		iL	21 07 42					
		iL	21 11 42					
		iL	21 17 42					
		M	21 19 24		*8,500			
		F	23 16 36					
18		eS	21 15 48					
		L	21 20 48					
		M	21 21 30		*800			
		L	21 27 06					
		F	22 01 42					
19		L	3 12 42?					Barely noticeable.
		L	3 38 18					
21		L	11 43 42					
		eL	11 59 30					
		M	12 01 06		*300			
		F	12 44 30					Light off at 15h when other stations record quake.
22		L	3 24 42					
		L	3 53 24		*100			
		L	3 56 30					
22								Marked microseisms at 5h 31m 18s, amplitude *200.
23		L	8 05 30		*50			
		F	8 29 06					
27		e	1 25 18					
		eL	1 33 54					
		M	1 41 36		*100			
		F	2 25 18					
28		S?	7 00 00					San Salvador, P not recorded.
		iL	7 04 06					
		M	7 04 30		*800			
		F	7 42 18					
30		e	7 30 48?				6,790	One of the largest disturbances we have ever recorded.
		eP	7 32 00					
		e	7 35 18					
		e	7 37 00					
		eS	7 40 18					
		iL	7 44 36					
		iL	7 48 00					
		L	8 14 00					
		L	8 15 30					
		L	8 16 30					
		M	8 19 00		*25,000			From 8h 17m to 9h 15m a number of swings of very large amplitude.
		L	10 15 36					
		F	12 39 42					
30		L	17 49 00					
		eL	17 50 18					
		M	17 51 30		*700			
		F	18 23 48					

*Trace amplitude.

Canada. *Victoria, B. C. Dominion Meteorological Service.*

Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instruments: Wiechert, vertical; Milne horizontal pendulum, North. In the meridian.

Instrumental constant. T_0 ..18. Pillar deviation, 1 mm. swing of boom = 0.54″.

Date.	Char-acter.	Phase.	Time.	Period T.	A_E	A_N	Dis-tance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Apr. 16		P	4 28 55					
		L	4 37 21					
		M	4 40 49		*100			
		F	4 50 14					
17		P	11 35 36				7,500	Japan.
		S	11 44 31					
		L	12 00 53					
		M	12 15 16		*1,200			F merges into next quake.

Date.	Char-acter.	Phase.	Time.	Period T.	Amplitude.		Dis-tance.	Remarks.
					A_E	A_N		
Canada. *Victoria, B. C. Dominion Meteorological Service*—Contd.								
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Apr. 17		M	13 58 12		*400			
		F	14 30 03					
17		P	21 00 56				4,530	Southern Mexico.
		S	21 07 12					
		L	21 11 20					
		L	21 16 16					
		M	21 24 39		*9,500			
		F	23 11 45					
			Vertical		A_z			
		P	*21 01 03*	*4*			*3,870*	
		S	*21 06 43*	*8*				
		L	*21 15 27*	*20–24*				
		M	*21 23 43*	*24*	*29*			
18		P	21 10 26				1,710	Probably Alaska.
		S	21 13 23					
		L	21 19 17					
		M	21 23 42		*1,500			
19		L	3 18 47					
		M	3 21 15		*200			
		F	3 27 38					
21		L	12 03 01					
		M	12 13 26		*300			
		F	12 55 05					
22		L	3 24 42					
		M	3 33 33		*200			
		F	4 07 00					
23		P?	7 47 35					
		L	7 58 31					
		M	8 05 38		*200			
		F	8 20 52					
27		L	1 13 48					
		M	1 18 43		*200			
		F	1 35 55					
28		L	7 10 29					
		M	7 17 26		*600			
		F	7 42 43					
30		P	7 29 14				5,750	Probably South America.
		S	7 36 37					
		L	7 48 54					
		M	8 03 11		*34,500			Light off from 16h 43m to 17h 45m when other stations record quake.
		F	13 28 15					
			Vertical.		A_z.			
		P	*7 29 00*	*4*			*5,320*	
		S	*7 36 00*	*12*				
		L	*7 53 12*	*24*				
		M	*8 00 30*	*24*	*29*			

*Trace amplitude.

SEISMOLOGICAL DISPATCHES.[1]

Tokyo, Japan, March 29, 1919.

A slight earthquake was felt here to-day at 9:30 a. m. No damage done. (Special observer.)

San Salvador, April 28, 1919.

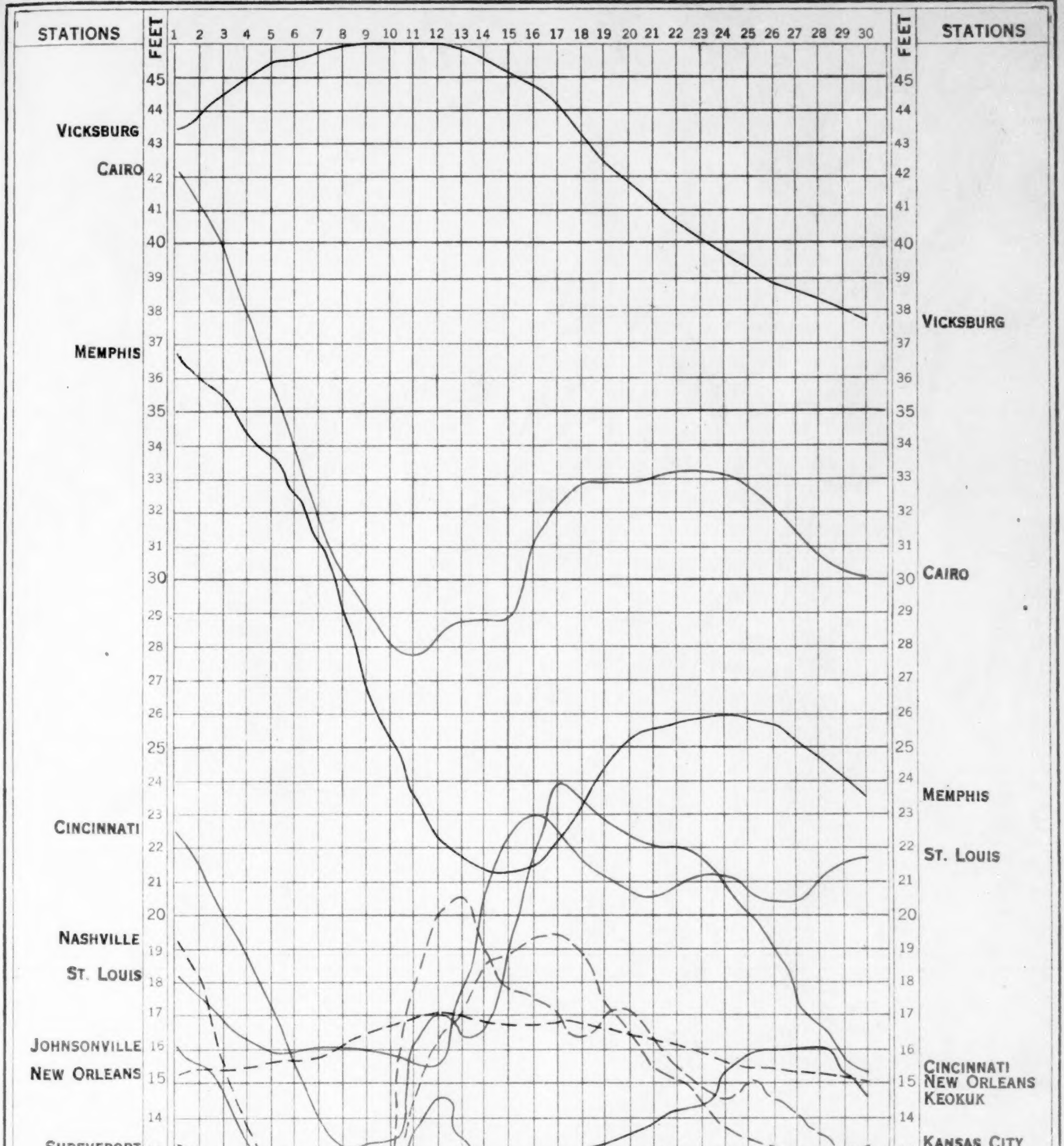
A violent earthquake occurred in this city at an early hour this morning. Later, about 20 additional shocks were felt, but of lesser violence. (Assoc. Press.)

Washington, D. C., April 29, 1919.

A severe earthquake occurred in San Salvador Monday morning (Apr. 28) at 1 o'clock, causing 49 deaths, injury to many persons, and considerable damage to property. (State Department.)

[1] Reported by the organization indicated and collected by the seismological station at Georgetown University, Washington, D. C.

Chart I. Hydrographs of Several Principal Rivers, April, 1919.



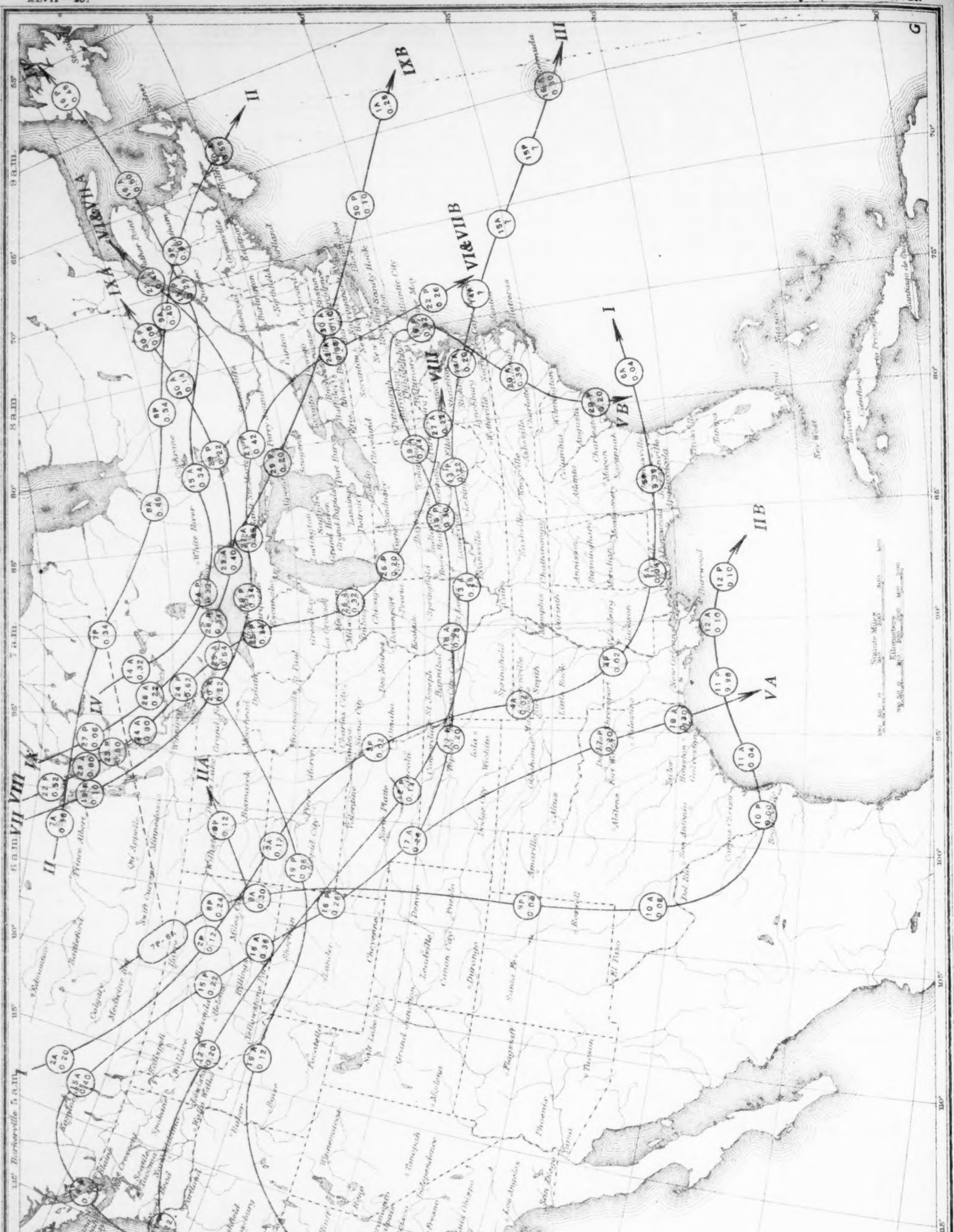


Chart II. Tracks of Centers of High Areas, April, 1919.
(Plotted by R. H. Weightman, Meteorologist.)

Chart III. Tracks of Centers of Low Areas, April, 1919.
(Plotted by R. H. Weightman, Meteorologist.)

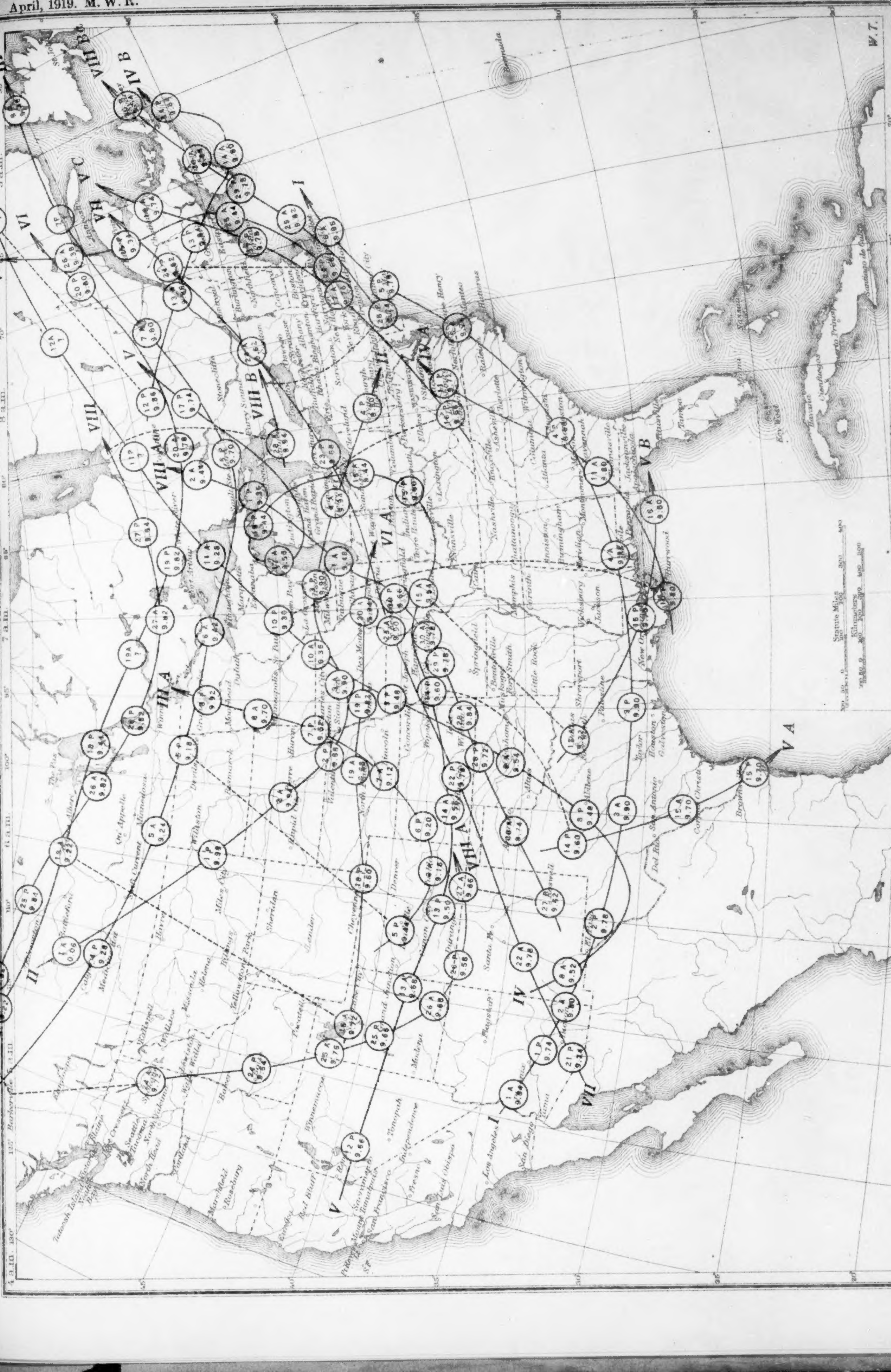


Chart IV. Departure (°F.) of the Mean Temperature from the Normal, April, 1919.

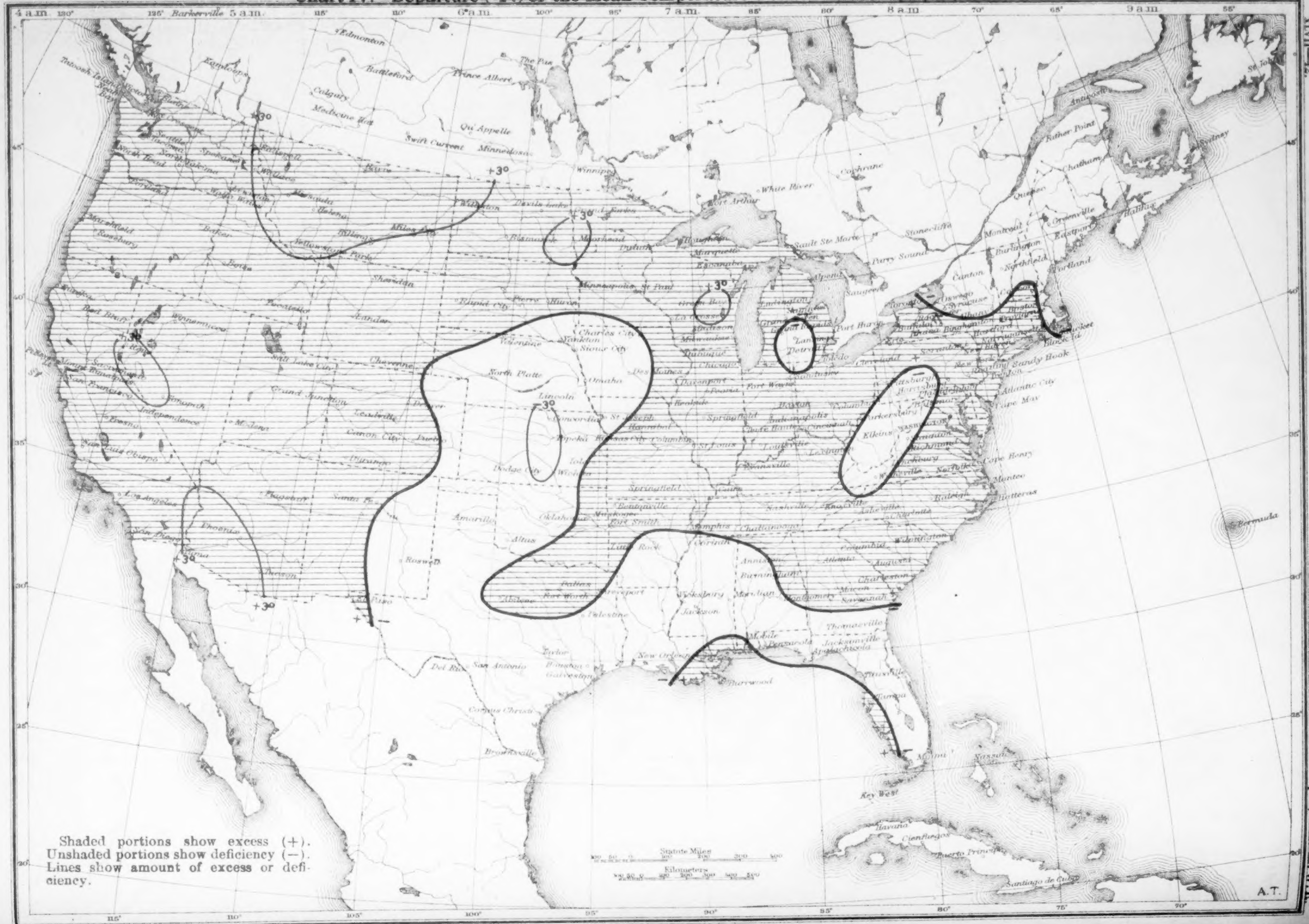


Chart V. Total Precipitation, Inches, April, 1919.

Chart VI. Percentage of Clear Sky between Sunrise and Sunset, April, 1919.

Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, April, 1919.

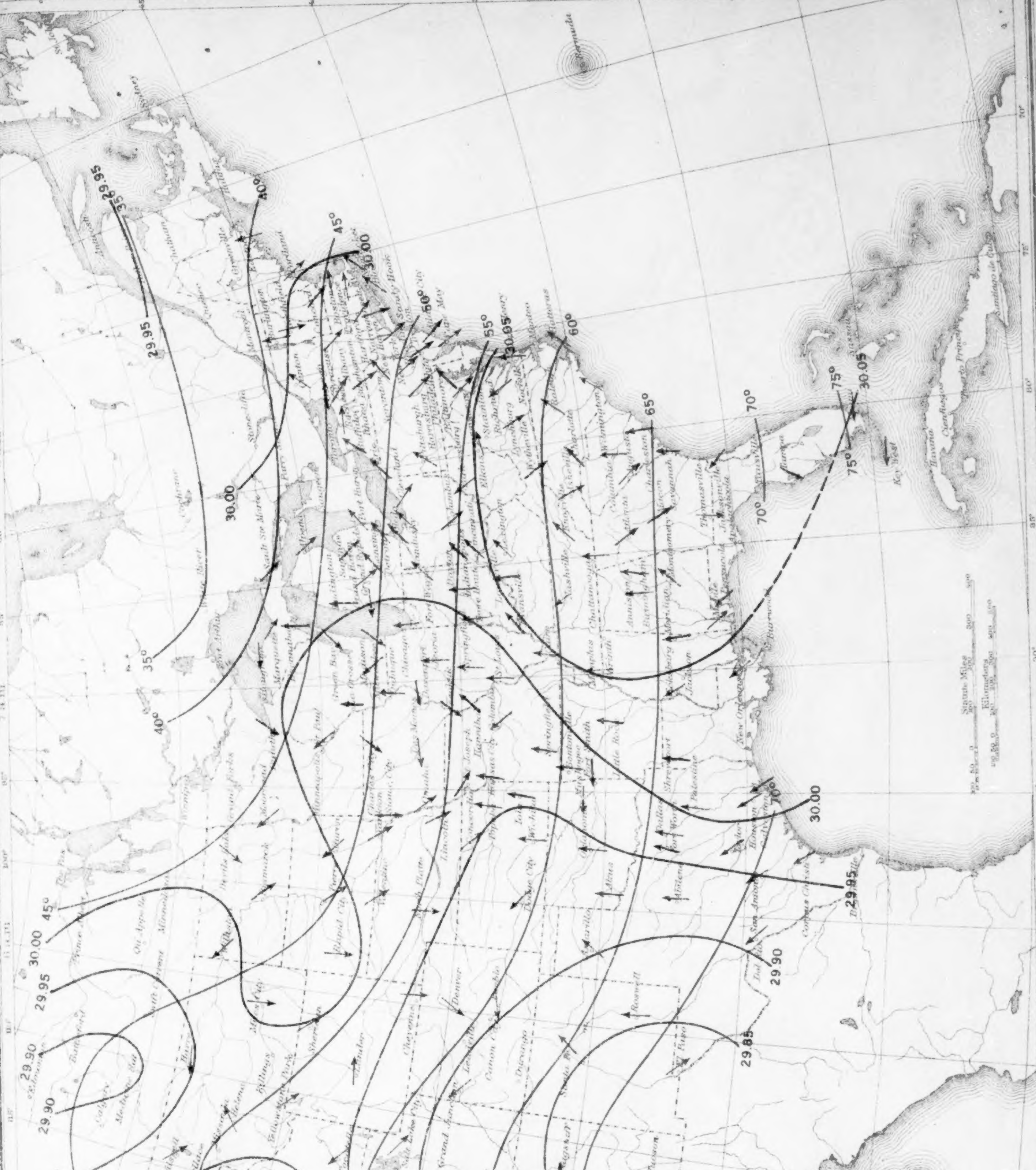


Chart VIII. Total Snowfall, Inches, April, 1919.

Chart IX. Weather Map of North Atlantic Ocean, April 14, 1919.

Chart IX. Weather Map of North Atlantic Ocean, April 14, 1919.

(Plotted by F. A. Young.)